REPORT

BY THE

COMMITTEE ON SOLAR PHYSICS

APPOINTED BY THE

LORDS OF THE COMMITTEE OF COUNCIL ON EDUCATION.

Presented to both Houses of Parliament by Command of Her Majesty.

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which, though sometimes entirely absent, generally surrounds the umbra and separates it from the general solar surface. In the penumbra indications of strong currents, often true cyclones, are observed, while the general surface is sometimes torn by these currents, and is seen projected in the form of *bridges* over the spot.

2. *Spectroscopic phenomena.*—The spectrum indicates that the blackness of a spot is due to absorption both general and selective. The selective absorption takes the form of a widening of *some* of the lines seen in the spectrum of the spot; and this character suggests that the chemical nature of the vapours in the spots may not always be the same. A contortion of certain of the spectral lines is also observed, which indicates that violent motion, most generally a down rush, is not uncommon.

3. *Their frequency.*—Hofrath Schwabe, of Dessau, was the first to ascertain that the state of the sun's surface as regards frequency of spots was by no means uniform, but was subject to an inequality, the average period of which was about 11 years.

Other inequalities, both of longer and shorter periods than the above, have been supposed to exist, but the 11 yearly period is the most prominent, as well as that of whose existence we are most assured.

Although the series of Schwabe is the first with pretensions to accuracy, yet Professor Rudolph Wolf[2] has endeavoured to render observations of sun spots made at different times and by different observers comparable with each other, and has thus formed a list exhibiting approximately the relative number of sun spots for each year. This list extends back into the 17th century, and is in many respects of great value, more especially in confirming past all doubt the existence of the 11 yearly period. Nevertheless, we must bear in mind that we have no continuous and wholly trustworthy data from which the relative number of the sun spots can be calculated until the time of Schwabe's observations. Schwabe began his observations in 1825, and his system was matured in 1832.

4. *Their distribution.*—In November 1853 Mr. Carrington began at Redhill, near London, an exceedingly accurate series of observations of sun spots, which extended until March 1861. These observations Mr. Carrington discussed at considerable length in a volume, the publication of which was aided by a grant from the fund placed by Her Majesty at the disposal of the Royal Society.[3] As the result of this discussion Mr. Carrington confirmed a previously

I.—PRELIMINARY OBSERVATIONS.

Before dealing with the proper subject-matter of our Report it appears desirable briefly to recapitulate from official documents the steps which led to the formation of this Committee and to state its object.

In the year 1875 the Royal Commission on Scientific Instruction and the Advancement of Science, in their eighth and final Report, strongly recommended the establishment by the State of an observatory for solar physics They stated that their opinion is confirmed by the action of foreign countries in this matter, observatories for astronomical physics having been already established in various parts of Italy, while their immediate erection had been decided upon in Berlin and in Paris. The Royal Commission further expressed a hope that similar institutions might be established in various parts of the British empire, and they particularly called attention to the great advantages that India afforded for continuous observations at certain high-level stations, which are so important in this matter. In 1876 a large and influential deputation from the British Association had an interview with the then Lord President of the Council, the Duke of Richmond and Gordon, with the view to urge on the Government the necessity for taking action on this and other recommendations of the Royal Commission. In replying to that deputation the Duke of Richmond stated that Mr. Lockyer had been transferred from the War Office to the Science and Art Department, and that facilities were being afforded him for carrying forward the researches bearing on this subject, in which he had been engaged for several years.

Shortly afterwards a memorial was presented by a large number of eminent men of science on the same subject. They based their appeal for the formation of an observatory for astronomical physics on the fact that in the opinion of a considerable number of scientific men there was a more or less intimate connexion between the state of the sun's surface and the meteorology of the earth, and they called attention to the fact that recent independent investigations on the part of several persons had led them to the conclusion that there was a similarity between the sun spot period, periods of famine in India, and cyclones in the Indian

centre of the disc has led to the belief that they consist of patches of luminous photospheric matter existing above the general level.

We have also evidence that this luminous matter has ascended to its elevation from beneath, and that faculæ consist of currents of relatively hot matter carried upwards from below, while sun spots consist of currents of comparatively cold matter carried downwards from above.

4 *Registration of faculæ*—The positions and areas of the faculæ which appear on the sun's disc have been since July 1873 systematically measured at Greenwich by the Astronomer Royal, and the Italian observers have also given attention to them

(3.) *Mottled structure of the surface*

Sir Wm Herschel[12] was probably the first to remark that when the sun's disc is observed with a powerful telescope it presents to the eye a brightness by no means uniform, but made up of numerous bright and dark patches, existing side by side so as to give the whole a mottled appearance, and he further stated that the pores, as he called them, were small spots. This has been abundantly established by the spectroscope

M. Janssen has recently been able to obtain admirable photographs, not only exhibiting the structure in detail, but likewise registering the changes which take place in it from time to time

(4.) *The Sun's atmosphere.*

1. *Evidence afforded by the darkening of the limb*—When we view the sun's disc through a telescope, or take a photograph of it, we find that the limb is less luminous than the centre. This leads us to believe that the luminous layer of the sun, or *photosphere* as it is termed, is surrounded by a comparatively cold absorbing atmosphere. Such an atmosphere would act in this way:—The light which reaches us from the limb would have to pierce through a greater depth than that which comes from the centre of the disc, and hence the former would be more absorbed than the latter, and the limb would therefore appear to us less luminous.

2. *Evidence afforded by Eclipses.*—On the occasions of total solar eclipses the eclipsed disc is observed to have irregular appendages around it which have been termed *red flames,* and by observations of eclipses from 1842 down-

a sum of 500*l.* was taken in the estimates for the expenses of the Committee on Solar Physics, and the present Committee was formed to make trial of methods of observation, to collect observed results, to find out what is being done in foreign countries, to collect as far as possible and bring together all existing information on the subject, and finally to reduce the Indian observations which have been made since the time when Mr. Meins was sent to India. The Committee made a preliminary report last year, which was presented to both Houses of Parliament, and has been published.

Having thus briefly described the circumstances which led to the appointment of the Committee, we proceed to mention the state of our knowledge at that time respecting the various branches of the subject, not attempting to give a complete scientific history of these, but only such a sketch as will show more clearly the direction in which it appears that this inquiry should be pursued in the future.

In considering the physics of the sun, we should naturally begin with the sun itself, and then go on to terrestrial phenomena, as regards some of which, though at first sight there might appear to be little relation between them and the sun, a connexion has since been established, or rendered more or less probable.

II.—STATE OF OUR KNOWLEDGE AT THE TIME OF THE APPOINTMENT OF THE COMMITTEE IN 1879.

SOLAR PHENOMENA.

(1.) *Sun Spots.*

The existence of black spots on the sun's disc is noticed in the ancient annals of the Chinese empire. In Europe they were first scientifically observed by Galileo, Fabricius, and Scheiner shortly after the invention of the telescope, and it was early deduced from their behaviour that the sun revolves about an axis in about 26 days.

1. *Telescopic phenomena.*—In a telescope, spots present very varied appearances. As a rule there are three shades of darkness visible, the *nucleus* (darkest) [1]* often seen in the central regions of the *umbra*, which is less dark; while surrounding the umbra there is the region of the *penumbra*,

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* The numbers thus printed refer to the list of papers given at p. 70.

least frequent at or about years of minimum sun spot frequency.[17]

3. *Their distribution over different months of the year.*—It has been shown by Kaemtz that European, and by Loomis that American auroras occur most frequently at or about the equinoxes.[18]

4. *Their simultaneity at various stations.* — It was known at a comparatively early period that great auroral displays are seen simultaneously at stations widely apart.

5. *Professor Loomis's remarks.*—As the result of 251 separate observations of the aurora, embracing the entire series made by Herrick and Bradley at Newhaven, U.S., from 1837 to 1854, Prof. Loomis[19] concludes that auroral displays in the middle latitudes of America are generally accompanied by an unusual disturbance of the sun's surface on the very day of the aurora.

(3.) *Earth Currents.*

Their general character. — They consist of electric currents taking place in the earth, whose existence was first discovered by Mr. Barlow,[20] but Mr. C. V. Walker[21] was probably the first who studied systematically the laws of these phenomena. They are now recorded continuously by photography at the Greenwich observatory.

Earth currents are particularly violent during magnetic storms, on which occasions they have their directions frequently reversed, but they are also observed, though to a very much smaller extent, during periods of comparative magnetic calm

(4.) *Magnetic Diurnal Variations.*

1. *Their nature.*—A delicately suspended magnet is never quite at rest, but has oscillations of various periods, one of which depends on the hour of the day. This last is called the diurnal variation, and its extent is called the diurnal range. The diurnal variations commonly referred to are —1, variations of declination; 2, variations of the horizontal component of the earth's magnetic force; 3, variations of its vertical component. These three taken together express the whole magnetic change at the place of observation.

2. *Their distribution over various years.*—Lamont[22] was the first to observe the signs of an inequality in the yearly values of the Munich diurnal declination ranges. In 1852 Sabine[23] pointed out that this inequality corresponded with the solar inequality previously discovered by Schwabe,

entertained suspicion that spots are grouped more or less round the equatorial regions of the sun, never by any chance appearing at the poles.

He likewise showed that at certain times there is a tendency in spots to confine themselves to latitudes very near the solar equator, while at other times they seek by preference somewhat higher latitudes, and that the same course is simultaneously pursued by spots whether north or south of the solar equator.

Dr. Smysloff, of the Wilna Observatory (*see* Appendix to this Report, page 152), has drawn attention to the fact that during certain times spotted areas appear most on the northern, while during other times they seek by preference the southern, hemisphere of the sun. He shows, however, that if we take a sufficiently long period (the three years, 1869–70–71, for instance) the total areas of the northern and southern spots are nearly equal.

Dr. Smysloff has confirmed Carrington's observation that spots on an average appear principally between 12° and 20° latitude in the northern as well as in the southern hemisphere, from which latitude they diminish rapidly in size and number towards the equator, and more gradually towards the poles.

More recently M. Sporer, in conformity with the previous observations of Carrington, has shown that spot activity, as deduced from the records at his disposal, appears to advance towards the solar equator, rising to a maximum when at 18° solar latitude, then diminishing until at 5° or 6° it seems to be exhausted. Afterwards some cause brings out spots in the higher latitudes again, and the same advance towards the solar equator is repeated with a maximum about 18°.

5. *Their proper motion.*—Mr. Carrington [4] has shown that spots have a proper motion of their own depending on their heliographic latitude, those near the solar equator moving faster than those further from it.

Mr. Carrington,[5] as the result of his observations, suspects that there is a tendency in spots near one another to diverge.

6. *Their nature.*—Professor Alexander Wilson, of Glasgow, in 1773,[6] was the first to bring forward evidence indicating that spots are phenomena which take place below the general level of the solar surface, pits in fact of which the penumbra forms the sloping sides and the umbra the bottom. More recently Kirchhoff has imagined that spots are phenomena taking place above rather than below the

leads to an increase of mean annual temperature at the Cape leads equally to a dissipation of sun spots

Dr. W. Köppen,[41] in 1873, discussed at great length the connexion between sun spots and terrestrial temperature, and found that in the Tropics the maximun temperature occurs fully a year before the year of minimum sun spots; while in the zones beyond the Tropics it occurs two years after the minimum. The regularity and magnitude of the temperature wave is most strongly marked in the Tropics

Mr. Blanford[42] has recently shown that in certain Indian stations a low annual temperature is associated with, if it is not caused by, an unusually large rainfall and a great amount of clouds This is a result in accordance with the conclusions previously enunciated by Professor Piazzi Smyth.[43] Records of maximum and minimum temperature must not therefore be too closely associated with maximum and minimum of solar action

(4.) *Storms.*

Dr. Meldrum,[44] of the Mauritius Observatory, found in 1872, from an analysis of the records of about 30 years' observations, that there are most cyclones in the Indian Ocean in years when there are most sun spots, and fewest cyclones when there are fewest sun spots.

In 1873 M. Poey[45] pointed out a similar coincidence between the hurricanes of the West Indies and the years of maximum sun spots. He enumerated 357 hurricanes between 1750 and 1873, and stated that out of 12 maxima 10 agreed.

In 1877 Mr. Henry Jeula, of Lloyd's, and Dr. Hunter[46] found that the per-centage of casualties on the registered vessels of the United Kingdom was $17\frac{1}{2}$ per cent greater during the two years about maximum than during the two years about minimum in the 11-year cycle.

(5.) *Rainfall—heights of rivers and lakes*

In 1872 Dr. Meldrum[47] showed that the rainfalls at Mauritius (observed since 1851), Adelaide (1839–1860), and Brisbane (1860-1871), were greater generally in the maximum than in the minimum sun spot years Shortly afterwards Mr. Lockyer[48] showed that the same law holds with the rainfalls at the Cape (1847–1870) and Madras (1843–1849) In 1876 Dr. Hunter,[49] Director General of Statistics in India, examined the rainfall at Madras from

Royal for the manner in which he has placed all the information bearing on the subject in the Royal Observatory at their service.

(2.) *Circular to Solar Observers.*

The Committee after a preliminary inquiry into the subject matter on which they had been requested to report, considered it desirable to communicate with men eminent in solar inquiry, with a view of obtaining suggestions and ascertaining to what extent they might hope for help.

The text of the circular letter is as follows:—

"Science and Art Department,
"South Kensington, London, S.W.,
31st day of December 1880.

"Sir,

"I have been requested by the Committee appointed to advise on the methods of carrying on observations in Solar Physics to forward to you the accompanying documents. You will perceive that the Lords of the Committee of Council on Education have taken into consideration some of the recommendations of the Royal Commission on the advancement of Science, supported by the representations of various scientific men in favour of the establishment of an Institution for research in Astronomical Physics. In the first instance, Professors Stokes and Balfour Stewart, and General Strachey, R.E., were requested to report how far the observations to which the memorialists refer might for the present be conducted with the means already in existence at South Kensington, supplemented by such observations as the Indian Government are either already making or might be found willing to undertake.

"In consequence of the report of these gentlemen the Government appointed a Committee consisting of Professors Stokes and Balfour Stewart, General Strachey, R.E., Mr. Norman Lockyer, Captain Abney, R.E., and Lieut.-Col. Donnelly, R.E., with certain funds at their disposal, to make trial of, and advise as to, the methods of carrying on and reducing such observations.

"This Committee has now been in existence for more than a year, and the main points to which they have directed their attention are shown in the printed page of this letter. It has seemed desirable to them that I should communicate to you and others interested in the subject their views regarding Solar Research, in the hope that you will favour

"The Committee hope that they have before them instruments, both thermometric and chemical, by which ultimately a good record of the actinic power of the sun may be obtained. A printed description of one of these, the thermometric apparatus, is herewith enclosed.

Spectroscopic Observations.

"The Committee also attach much importance to spectroscopic observations of solar phenomena and laboratory experiments in connexion therewith. Such observations and experiments are now being carried on at South Kensington, and a pamphlet is herewith enclosed that will explain to you one method which has been employed in dealing with sun spot spectra.

Reductions of Observations.

"A simple method of determining from the solar photographs the positions and areas of the spots, with a view to their subsequent discussion, is at present under the consideration of the Committee.

"The enclosed pamphlet will explain to you in what manner the Committee propose to reduce the positions of the sunspots recorded by the Indian photographs.

"The Committee have before them an inquiry as to whether, besides the recognised sun spot cycle, there may be periodic inequalities common to solar and terrestrial phenomena. A pamphlet on this subject by a member of the Committee following out a method described in a paper read before the Royal Society, and printed in the proceedings of that Society, is herewith enclosed."

The replies to this circular are published in an appendix to this Report. They embody suggestions of much value, which have received the full consideration of the Committee, and which have assisted them in arriving at those conclusions and recommendations which will be afterwards mentioned.

(3.) *Correspondence with the Indian Government.*

1.—*Sun Pictures.*

Prior to the appointment of the Solar Physics Committee a correspondence had taken place which had resulted in daily sun pictures being taken in India. In order that the

wards, it has been proved that the flames really belong to the sun, from the surface of which they occasionally extend to the height of 100,000 miles or more. These red flames may now be seen, by means of a spectroscopic method, whenever the sun is visible.

The spectroscope has revealed to us the fact that the red flames are only the most prominent portions of a coloured solar atmosphere, surrounding the sun's disc to an average height of 4,000 miles, which has been termed the *chromosphere*, while from observations made during the eclipses of 1870 and 1871 there was reason to believe that between the chromosphere and photosphere there existed a stratum of dense metallic vapours 1,000 miles high, by the absorption of which, it was thought, the Fraunhofer lines were produced; this stratum has hence been termed the *reversing layer.*

Beyond the chromosphere and the red flames we have the solar *Corona*, which observation has proved to be, in part at all events, an undoubted solar appendage. I consists of faintly luminous matter, extending perhaps to the distance of a million of miles or more around the solar disc. This luminous matter is not, however, by any means regularly distributed around the disc, nor is it always of the same extent and lustre.

3. *Chemical nature of the Atmosphere.*—Careful study by Kirchhoff and others of the Fraunhofer lines and of the bright lines in the lower part of the solar atmosphere has shown many of them to be coincident with bright lines seen in the spectra of metallic elements common on the earth, and it has been concluded, therefore, that these substances exist also in the atmosphere of the sun. Many of the lines, however, have no terrestrial equivalents, and their origin is doubtful.

The solar atmospheric lines are not all of the same length, *i.e.*, they do not all extend to the same distance from the sun, and the various lengths of the lines have rendered it possible to determine the locus of the particular substances indicated by them.

Extending to the greatest distance is an unknown substance (but probably a gas lighter than hydrogen), represented by a line in the green at 1474 of Kirchhoff's scale. Next in order of length come the hydrogen lines, and these vary among themselves, the blue line F being longer than the line C in the red. Then follow, with a constantly decreasing length, the lines of magnesium, calcium, and sodium, and these are succeeded in the lowest part of the atmosphere by a crowd of lines representing a great number

proposed. The other instruments may also be sent to England, and will be placed in the custody of the Science and Art Department which has offered to take charge of them.

I have, &c.
(Signed) SALISBURY.

India Office, Westminster, S.W.,
24th October 1877.

SIR,

WITH reference to my letters of the 31st August and 15th September regarding the engagement of Mr. M. Meins as solar photographer in India, I am directed by the Secretary of State for India to forward herewith, for your information, copy of a despatch, which has been addressed by his Lordship to the Government of India, from which you will perceive what steps have been taken to carry out the suggestions and recommendations made by you with regard to the observation of solar phenomena in India.

I am also to acquaint you that a communication has been made to the Astronomer Royal from this office, requesting him to favour the Indian Government with the loan of a photoheliograph tube to replace the one about to be sent home for examination.

His Lordship considers that Mr. Meins should take with him a sufficient supply of chemicals to enable him to commence his observations with as little delay as possible on arrival in India. I am to request you, therefore, to be good enough to state what steps you would propose to take to ensure the provision of the necessary chemicals, and to charge yourself with the task of purchasing an adequate stock at a cost not exceeding 30*l.*

I am to request you, in conclusion, to inform Mr. Meins that he should hold himself in readiness to proceed to Calcutta about the beginning of November, and that an advance of one month's pay, calculated at the exchange of 1*s.* 9½*d.* to the rupee, will be made to him.

I am, &c,
(Signed) LOUIS MALLET.

J. Norman Lockyer, Esq., F.R.S.

On the 11th December 1877, Professors G. G. Stokes and Balfour Stewart and General Strachey, in a letter which they addressed to the Right Hon. Viscount Sandon, M.P.,

years of minimum sun spots correspond to years of fewest magnetic storms.

3. *Their distribution over different months of the year.*—Sir E. Sabine[14] in discussing the results of the colonial observatories has shown that magnetic storms are unequally distributed over the various months of the year. In Toronto there is a manifest preponderance of such storms about the equinoxes, while at St. Helena there are likewise subsidiary maxima at the equinoxes. At Hobarton, however, there is a manifest annual inequality, with hardly any traces of maxima at the equinoxes.

Mr. J. A. Broun,[15] by a somewhat different method of treatment, has shown that at Makerstoun in Scotland the mean disturbance of magnetic declination has its maximum at the equinoxes.

4. *Their simultaneity at various stations.*—It was known at a comparatively early epoch that magnetic disturbances occurred simultaneously at widely separated stations Alexander von Humboldt was the first to observe this, and the observation was fully confirmed by Gauss and Weber, and by subsequent observers.

5. *Professor Loomis's remarks.*—Professor Elias Loomis,[16] from a discussion of 135 cases of magnetic disturbance, embracing all the great magnetic disturbances regarded as such at Greenwich for a period of 23 years, comes to the following conclusions:—

(*a.*) Great disturbances of the earth's magnetism are accompanied by unusual disturbances of the sun's surface on the very day of the magnetic storm.

(*b.*) The great disturbance of the sun's surface which accompanies a terrestrial magnetic storm is generally heralded by a smaller disturbance three or four days previous, succeeded by a comparative calm which immediately precedes the magnetic storm.

(2.) *Auroral Displays.*

1. *These accompany magnetic storms.*—While auroral displays are very frequent, if not continuous, near the magnetic pole, it was early observed that in lower latitudes they are accompaniments of magnetic storms.

2. *Their distribution over various years.*—Loomis and others have shown that we have most frequent auroras during years of maximum sun spots, and that they are

of the European photographer may be guarded against in the future.

It is believed that skill in the necessary manipulations for successful photography could be readily acquired by intelligent natives, and that when this had been done further assistance from this country for the supply of photographers would not be needed.

I have, &c.
(Signed) G. G. STOKES.

This letter was submitted by the Secretary of State for India in Council for the consideration of the Government of India, and in February 1880 the India Office acquainted the Committee with the measures taken to resume the series of daily photographs of the sun's disc, viz., that Major General J. T. Walker, Surveyor-General of India, had expressed his readiness to undertake the solar photography as a part of the operations of the Trigonometrical Survey Office at Dehra, under the supervision of Mr Hennesey, but that he inquired as to the desirability of taking larger pictures than those now obtained from the photoheliograph. In compliance with Major General Walker's suggestion, the appointment of a European surveyor of the 2nd grade as solar photographer was sanctioned, and the India Office requested the Solar Physics Committee to give their opinion whether photographs on a larger scale might be preferably taken.

As to this point Mr. Lockyer undertook some preliminary experiments, and in August 1880 the Solar Physics Committee reported to the India Office that by a small outlay the photoheliograph in use in India could be made of more practical use. The alterations would consist in replacing the magnifying lens by one of shorter focus to enable photographs of the sun to be taken of eight inches in diameter instead of the pictures of four inches diameter hitherto obtained. The Committee proposed to transmit specimens of photographs on this larger scale. Details of the further action taken, in concert with the India Office, to provide an efficient instrument for solar photography in India will be found under the sub-section relating to the photoheliograph.

In the month of November 1880 it was reported that the work of solar photography was being carried on syste-

maximum and minimum declination ranges corresponding to years of maximum and minimum sun spot frequency. In the same year Dr. Wolf[24] and M. Gautier[25] independently remarked the same coincidence.

Professor Loomis[26] has confirmed this by bringing together and comparing declination ranges and sun spots from 1777 to 1870 inclusive, and he has made a similar comparison between auroral displays and sun spots.

Mr. Ellis[27] has shown, from a discussion of 37 years' observations at Greenwich, that the diurnal ranges of horizontal force as well as of declination vary directly with the frequency of sun-spots.

3 *Their dependence on the position of the sun.*—In middle latitudes declination ranges are greatest in summer and least in winter.[28] The form of the solar diurnal variation of declination is in the southern hemisphere the reverse of what it is in the northern.[28]

Mr. J. A. Broun has shown (as was first indicated by Sabine [28]) that at the equator the form of the solar diurnal declination variation reverses itself at the equinoxes, at which time there is an extinction of the mean movement [29]

4. *Correspondence between the shorter sun spot inequalities and the shorter declination range inequalities.*—Professor Stewart [30] has exhibited the intimate nature of this correspondence, and endeavoured to show that the declination range inequalities invariably in point of time lag behind corresponding solar inequalities; a result which has since been to some extent confirmed by Mr. Ellis.[31]

Mr. Ellis has likewise shown a similar correspondence between solar inequalities and the inequalities of the horizontal component of the earth's magnetism.

5. *Suspected progress from west to east of declination range inequalities.*—Shortly before the appointment of the Solar Physics Committee, Professor Stewart, in conjunction with Morisabro Hiraoka,[32] brought evidence to show that declination range inequalities travel from west to east, and faster than ordinary weather. In this respect Trevandrum was found to lag 9·7 days behind Kew. This has since been confirmed by comparing together the declination ranges at Kew and Prague, and, lastly, by a comparison of the declination ranges at Toronto and Kew.

6. *Comparison between the declination curves at Stonyhurst and Kew.*—A limited comparison of this nature has been made by the Rev. Walter Sidgreaves and Professor Stewart,[33] who found that during times of comparative calm

fully in accord with the Famine Commissioners as to the importance of following up such clues as they afford, and of pursuing with all the means at our command the investigation of the class of phenomena to which they belong. It has happened again and again in the past history of science, that hypotheses which, in their original form, were more or less erroneous, have nevertheless been most fruitful in their results. In giving system and definite purpose to research, they have served a most useful office; and, although the course of their verification may have resulted in demonstrating their error, the same process has brought to light the germs of new and unsuspected truths, which might have long remained hidden but for the stimulus to investigation afforded by rejected theories.

"One branch of inquiry, which has undoubtedly received much stimulus since the supposed variation of the rainfall with the sun-spot cycle, has brought into vivid prominence the unquestionable fact that all meteorological phenomena depend on, and must vary with, the solar heat, is that of the physical changes of the sun itself, and the probable variation of its radiant intensity. The visible physical changes of the solar surface are a subject for which data are being collected by the officers of the Great Trigonometrical Survey under General Walker, and I understand that new and more powerful instruments than that hitherto employed will be placed at their disposal for photographing the solar disc as soon as they can be obtained from England. Mr. Hennesey, of the Great Trigonometrical Survey, has also made important observations on the radiant energy of the sun, and I have lately had compared at the Alipore Observatory a Stewart's actinometer which has been sent to him for carrying on these observations with greater advantage. Observations with a similar instrument have been made regularly at the Alipore Observatory during the past year, and have been lately sent home to the Solar Physics Committee for examination and discussion. I intend to continue these observations, which can hardly fail to yield some facts of value; but the skies of Calcutta are by no means favourable for such work; and therefore preliminary steps have been taken to obtain actinometric observations from Lé, the elevation and clear atmosphere of which station promise most satisfactory results. An actinometer has been received from home for use at Lé, and is now being compared at Alipore, and I have been in communication with Mr. Ney Elias (who has promised to superintend the work) with a view to the final arrangements.

"The only step of importance that remains to be taken

an immediate graphical and visible indication of the power of the sun, should also be employed. Now of this latter instrument we have no knowledge in India, and although we might train an observer to the use of the Stewart actinometer without much difficulty, in order to learn the use of the latter instrument, it would be necessary that he should receive his training at home. Moreover, an intelligent man, trained at the head-quarters of an observatory devoted to solar physics, would be more likely to acquire an intimate and personal interest in the objects of the inquiry than one picked up in India, and furnished merely with such technical training in the use of a single instrument as we could give him here; and of the beneficial influence of such personal interest on his work, and in preserving him from the temptations to which I have alluded, there can, I think, be no question.

"I would recommend then that the Secretary of State be moved to sanction the selection by the Solar Physics Committee of a sapper of good steady habits and marked intelligence, and that he be trained to his work in the manner proposed. His salary could be settled at home; it should not be less than that paid to the sapper sent out to take the solar photographs at Dehra. Indeed it should be somewhat more. On this point, Mr. Elias remarks:—

"I hope you will move Government to grant him good pay, otherwise he will be very uncomfortable here, for his expenses would be much greater than in India (except for rent), and if discontented he is not likely to have his heart in the work."

"I would also recommend that the Secretary of State be moved to sanction the provision of the instrument devised by Mr. Winstanley, to which reference has been made; it should be verified and approved by the Solar Physics Committee."

The Government of India in reviewing the foregoing report remarks:—

"The request for a scientific assistant to the Meteorological Reporter has before been under the consideration of the Government of India. The need of such an officer was recognised, but final decision of this matter had, in 1879, to be postponed owing to financial pressure. The Government of India now considers that for the improvement of the meteorological reports on the lines of the Meteorological Reporter's proposals the permanent addition of another scientific officer to the department is indispensable. It is most desirable also to provide that in case of the Meteorological Reporter's sickness or absence from head-quarters the daily

effected, perhaps, in the best way by the observation of thermometers whose bulbs are deeply sunk in the earth.

"Two days past I transmitted to your address a copy of 'Reduction of Greenwich Meteorological Observations, 1854-1873, 1849–1868, and *Earth Thermometers*, 1847–1873.' I ask leave to call your attention to Plate IX. and Plate X. of that work, and to remark the following inferences. First, that the varying warmth of the surface, travelling downwards with diminished power (as is shown in both plates), originates *from an external cause*, which cause in all probability is the solar radiation. Second, the mean temperature of the surface and of lower strata (as is shown in Plate X.) varies considerably from year to year, *indicating considerable variation* in the energy of the external cause, which (as is mentioned above) I conceive to be the solar radiation.

"Thermometers of this kind were first introduced at Paris, and that example was followed successively at Edinburgh and at Greenwich. I know not whether any observations of the Paris thermometers have been published Those made at Edinburgh (which are very complete) are published by Professor Piazzi Smyth; they agree closely in their results with those at Greenwich. But the Edinburgh thermometers were destroyed about three years past by the act of a maniac, and those at Greenwich alone are in existence and active use.

"The outfit expense of these thermometers is small, and the trouble of using them is almost nothing. It appears to me very desirable that they should be introduced in the scheme of Indian observations."

Mr. Henry T. Blanford, Meteorological Reporter to the Government of India, writing in 1881 to the Secretary to the Government of India Home Revenue and Agricultural Department, remarks:—

"Another class of observations which I have undertaken, and which Sir George Airy considers may be useful in throwing light on the question of the variability of the sun's heat, are those of the temperature of the ground.

"These observations have now been made at Alipore for three years and for one year at Allahabad. That they will prove of great importance in connexion with meteorological inquiry I entertain no doubt, and indeed they have already yielded some facts of considerable interest which have been noticed in my official reports. Whether, however, the variations of temperature which have been observed have direct reference to the variations of solar radiant energy is,

10-inch by 10-inch plates. These additions to the instrument could be sent out and fixed in India, and could be got ready within six weeks from the receipt of the order. We are of opinion that the above described alterations of the photoheliograph in India would be of considerable service in forwarding research in solar physics, and we recommend their adoption.

"As to the opinion which General Walker appears to have formed that a more powerful instrument should be, if possible, employed in India, we would remark that from the experiments which we have been making at South Kensington, we are of opinion that an instrument to give pictures of the sun 12 inches in diameter could be employed without any difficulty in India.

"Such pictures have been taken at South Kensington with an instrument for a great part of which we are indebted to loans; but we believe that a thoroughly efficient instrument could be constructed for 500*l.*, and if that amount be placed at our disposal we will be glad to give the necessary supervision in the construction of an instrument to be sent to India.

"At the same time, as, for the objects more immediately in view, the 8-inch pictures will no doubt suffice, we are anxious that it should be understood that we in no way urge the construction of the instrument for 12-inch pictures at the present time if there should be any financial or administrative objections to such a course.

"The India Office at once sanctioned the expenditure necessary for the improvement of the existing instrument, and after communication with the Government of India accepted the Committee's offer to supervise the construction of a more efficient instrument at a cost not exceeding 500*l.*"

The Committee, whilst anxious to give effect to the wishes of the Government of India, were hindered by the serious illness of Mr. Dallmeyer from obtaining the modification of the small photoheliograph, and they therefore placed their own modified apparatus at the disposal of the Indian Government upon their undertaking to defray its cost, and subsequently under similar circumstances the large photoheliograph belonging to the Science and Art Department was made over to the Indian Government.

The above instruments were in use by Mr. Norman Lockyer in his laboratory, in the science schools, or in his observatory.

12. A small Gramme dynamo-electric machine with a 3 h.p. Brotherhood engine.
13. A Gramme hand lamp and the necessary connexions
14. A large spectrum grating of $1\frac{1}{2}$ inches square and 17,280 lines to the inch
15. A smaller grating about half the size and 8,640 lines to the inch.
16. A prismatic spectroscope with a power equal to seven prisms.
17. A heliostat by Spencer, of Dublin.

The above, together with the necessary equipment of cameras, all the property of Captain Abney, were in use in his laboratory.

2.—*Instruments lent by the India Office*

Soon after the appointment of the Committee some instruments, which had been returned from India with a view to their better preservation, and had been with this object transferred to the custody of the Science and Art Department, were placed at their disposal.

These instruments were as follows.—

1. A 6-inch telescope, equatorially mounted with declination, right ascension, and setting circles and finder complete, by Cooke, of York. To this instrument two spectroscopes belong, the one a stellar spectroscope, the other a solar spectroscope, having a dispersive power of 18 dense flint glass prisms of 60°: these were made by Hilger, of London. These instruments are the property of the India Office. An adapter has been made so that the grating spectroscope above mentioned can be used with this instrument.
2. A small transit instrument.
3. A standard and two journeymen clocks.
4. A chronograph.

The equatorial was erected in 1879, and has been in constant use ever since. The other instruments are still in the Science Museum, with the exception of the clock, which has been withdrawn for use with the Transit of Venus Expeditions.

5.—*Alterations to Small Photoheliograph.*

When the Indian Government suggested that it would be desirable to have larger pictures taken in India, experiments were tried with the photoheliograph belonging to the Royal Observatory, and it was found that by slightly lengthening the cone and using a new secondary magnifier it could be made to take 8-inch pictures.

As a result of these experiments a new camera end and new secondary magnifier have been sent to India to be adapted to the instrument already in that country.

6.—*Additional Instruments.*

It will be seen from the list previously given that the instruments in use have for the most part been placed at the disposal of the Committee either by Government Departments, the Astronomer Royal, or private individuals.

Since the appointment of the Committee other instruments besides those already referred to have been placed at its disposal for occasional use. These have in many cases been purchased by the Science and Art Department for use in the science school. Among the most important of these may be mentioned:—

1. A Stewart actinometer (the standard instrument) made by Casella.
2. 10-inch object glass by Cooke.
3. Intensity and quantity coils by Apps.
4. Measuring machine by Hilger.
5. Spectroscope by Cooke.
6. 15 by 15 in. camera.

The dynamo-electric machine and lamp lent to Mr. Lockyer by Dr. Siemens have since been purchased for this Department, and the smaller photographic lens has been mounted as an observing telescope for use with a large spectroscope.

7.—*New Sites for Temporary Buildings at South Kensington.*

The Science and Art Department, in consequence of representations made to them by the Committee, applied in April 1880 to the Board of Works for permission to utilise the vacant ground behind the post office in the Exhibition Road; permission was granted for the erection of temporary wooden buildings, and accordingly a room for photography

letter was circulated by desire of the Committee in July 1881:—

Science and Art Department,
London, S.W.,
13th July 1881.

SIR,

ON the 31st December last the Committee appointed to advise on the methods of carrying on Observations in Solar Physics had the honour of addressing you on the subject of their work, and the catalogue of sun pictures referred to in that communication has since been forwarded to you.

As one of the objects which the Committee consider very important is to bring together the Solar information which at present exists, they are very anxious to know whether it will be in your power kindly to assist them in this task by making very simple measurements of the areas and positions of sun spots from the pictures which you possess, such as are specified in the catalogue of sun spots already mentioned. The number of observations sought would be reduced to a minimum, while the amount of precision required for the purposes of the Committee would not be very great. If you consent to afford your valuable assistance in the manner thus indicated, the Committee will be glad to enter into communication with you, with a view to discuss details.

This letter was sent to the following:—

Dr. Bredichin, the Observatory, Moscow, Russia.
R. T. Ellery, F.R.S., Observatory, Melbourne, Australia.
C. Meldrum, F.R.S., Observatory, Mauritius.
Professor Pickering, Observatory, Cambridge, U.S.A.
Dr. Smysloff, Observatory, Wilna, Russia.

The replies received by the Committee to this circular are such as to evince the greatest readiness in all these solar observers to aid the Committee as far as they possibly can. In consequence of this valuable co-operation it is expected that the labour of collecting and publishing the solar information which at present exists will be materially reduced.

(6.) *Measurement of Sun Spots.*

The Committee have given great attention to the subject of the reduction of sun-spot observations with a view to being prepared to deal with the large number of daily photographs to be expected when the various observatories which have already promised co-operation are in full work.

subsequent action of the Committee may be made quite clear, this correspondence and the Memorandum which gave rise to it are given in this place.

Memorandum by Mr. Lockyer.

26 June 1877.

In accordance with the request made to me, I beg to send the following remarks on the Despatches dealing with the Indian instruments :—

1. Let me premise that solar research is now being specially carried on in Europe at—

(1.) Potsdam, in the new Sonnenwarte.
(2.) Paris, in the new physical observatory.
(3.) Rome and Palermo.
(4.) South Kensington, in connection with the Science and Art Department.
(5.) At Greenwich, Wilna, and other places it is carried on in a less special way.

2. In these European observatories, however, especially in the more northern ones, we are attempting to make bricks without straw, that is, the climate is such that the observations are often interrupted, at times for weeks together, while, in addition to this, in winter the sun's altitude is so small that fine work is impossible.

3. While this state of things holds in Europe, in India, on the other hand, one has an unlimited and constant supply of the *raw material*, by which I mean that here one can, if one chooses, obtain observations of the finest quality in sufficient quantity all the year round. I may even go further, and say that, limiting my remark to English ground, we have in India a *monoply* of the raw material.

4. I learn from the papers sent to me, that although most of the necessary instruments are already out in India, there is no immediate prospect of the establishment of a solar observatory on an extended scale for the purpose of securing observations over the whole field.

5. Although students of science cannot but regret that this is so, still there is no doubt that the new European establishments to which I have referred, and the proposed Russian observatory north of the Himalayas, render observations in India, over the whole field, of less vital importance than they were when the Indian observatory was first suggested.

to the period of maximum sun spots and will allow of a comparison being made with the results obtained in India in 1871.

"There is one new point (it is not necessary now to refer to the importance of registering the ordinary phenomena) to which I beg to invite the attention of the Committee.

"The discussion of the sun spot spectra recently observed at Kensington and of the prominence spectra observed at Palermo by Tacchini since 1872 throws some doubt upon the validity of some of the conclusions based upon the results obtained by the English and American Government Eclipse Expeditions in 1870.

"In that year at the moment of the disappearance of the sun a large number of bright lines was seen to flash out, and it was supposed that these lines composed the spectrum of a thin layer near the sun and were those the reversal of which produced the lines of Fraunhofer.

"Hence this layer has been termed, and generally accepted to be, the reversing layer. The conclusion seemed to be in harmony with the results obtained by Dr. Frankland and myself who gave reasons for showing that the region in which the absorption of the elementary bodies of greater atomic weight than hydrogen, magnesium, and sodium must be below the chromosphere. This view was put forward at a time when the elementary nature of the so-called elements was never questioned, and before any of the recent results had been obtained.

"The observations made by the Government Eclipse Expedition which went to India in 1871, showed that this flashing out of lines was a real phenomenon, but as the observation was a general one, and as during the eclipse the Fraunhoferic lines were invisible, there was no absolute demonstration of the identity of the two spectra.

"The facts, now beyond question, that quâ the same element the spectra of spots and flames differ, and that the spot spectra differ widely among themselves, throw great doubt upon the conclusion to which reference has been made.

"First, they seem to indicate that some of the absorption takes place at a higher level than that occupied by the so-called reversing layer.

"Secondly, they seem to indicate that many of the brightest lines seen during the flash to which reference has been made may be those seen thickened in spots or intensified in the prominences, although they do not occur except as excessively faint lines among the Fraunhoferic lines.

"In short, in 1870 the fact that the spot and prominence spectra are so widely different from the ordinary solar spec-

the value of the advice I can give, but I am second to none in the anxiety I feel for the progress of this work.

From the Secretary of State for India to the Governor General of India in Council.

India Office, London,
28th September 1877.

My Lord,

Para. 1. With reference to your Industry, Science, and Art Despatch, No. 3 of 1877, dated 16th February, requesting that the instruments recently in use at Roorkee observatory might be forwarded to this country, I have to acquaint you that I have received from Mr. Lockyer, well known in connexion with the study of solar physics, a memorandum* on the subject of the photoheliograph, a copy of which is forwarded herewith.

2. Having considered the suggestions made by Mr. Lockyer, and viewing the fact that a study of the condition of the sun's disc in relation to terrestrial phenomena has become an important part of physical investigation, I have thought it desirable to assent to the employment, for a limited period, of a person qualified to obtain photographs of the sun's disc by aid of the instrument now in India, on the terms explained in the letter† that I have caused to be addressed to Mr. Lockyer, a copy of which is enclosed.

3. The photographer engaged for this duty will leave this country about the beginning of November, and on arrival may probably be best placed under the orders of the Superintendent of the Trigonometrical Survey, who, in communication with Colonel Tennant, might propose for the consideration of your Excellency's Government the detailed measures for giving effect to the plan of operations suggested by Mr. Lockyer.

4. It will be distinctly understood that the expense of making these observations shall be restricted to what is essential for obtaining the photographs, and that no outlay is contemplated for buildings or other appliances other than of a purely temporary character, the cost of which will be comparatively insignificant. The photographs will be sent to this country for future examination.

5. The stand of the photoheliograph will be retained in India, and a fresh tube will be sent there to replace that used by Colonel Tennant, which should be sent here as

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* Dated 26th June 1877.
† Dated 15th September 1877.

voured to show that as a matter of fact such views are borne out by the phenomena of terrestrial magnetism and meteorology, but more conspicuously by those of terrestrial magnetism.

Mr. Lockyer came next, and lectured on the Chemistry of the Sun.

The last series was given by Captain Abney, who lectured on Spectrum Photography.

These various courses of lectures are published in "Nature,"[55] which may be referred to for details.

RESEARCH WORK.

(1.) *Solar Phenomena.*

1.—*Photoheliograph.*

Whenever conditions were favourable, photographic pictures of the sun were taken with the smaller photoheliograph until it was dismounted for service with the Eclipse Expedition, and subsequently the Transit of Venus Expedition.

The larger instrument has been tested and transferred to the Indian Government, which has sent it out to Dehra-Doon, in the North-West Provinces of India.

The new instrument now in course of construction will be used for taking large pictures of the sun and photographs of the spectra of spots.

2.—*Spectroscope*

a.—*Observatory Work with Spectroscope*

a. By means of one or other of the equatorials the spectrum of spots is examined as frequently as possible, and occasionally a search is made for prominences. Eye observations are also made.

d. The siderostat and a three prism spectroscope have been used for photographing the spectrum of sun spots.

b.—*Laboratory Work with Spectroscope.*

The laboratory work has for its chief object the comparison of the lines in the spectra of chemical substances with those observed in the spectra of the sun and stars. The routine work consists in obtaining a complete series of comparisons for each substance throughout the whole length of the spectrum, photography being employed as much as possible.

The reduction of the observations for the first portion of the complete map having shown that there is strong reason to suppose that the elements are in reality compound

by themselves. The various appearances of lines during reversal were also examined.

c.—*Discussions and reductions combining Observatory and Laboratory Work with Spectroscope.*

The routine discussions are as follows:—

a. Discussion of the coincidence or non-coincidence of metallic and metalloidal lines with the Fraunhofer lines.

b. Discussion of the lines seen affected in spots and storms, and of the corresponding lines in the spectra of metals.

c. Discussion and mapping of all the observations recorded in the case of each metal for all ranges of temperature, and comparison of lines with the Fraunhofer lines.

d. Discussion of sun spot observations.

e. Reductions necessary for the large solar spectrum map now in course of construction.

The occasional discussions have been as follows:—

a. A comparison for the region between λ 4120·0 and λ 4390·0. General result that within this region 38 lines have been found common to two or more metals.

b. The lines of the various metals given in Thalen's list have been compared together; with the result that 140 lines having identical readings in, at least, two spectra have been noted. In a few cases the truth of these coincidences has been tested by eye observations; and in others by reference to the photographic evidence.

c. A discussion of the lists of lines for the region between *B* and *b* seen by Young at Sherman in spots and storms has been made.

d. Discussion of the observations of the first spot examined at South Kensington has been completed and published as an appendix to the Report of the Committee, as illustrating the method which they consider should be adopted in these observations.

e. Discussion of a series of photographic comparisons made by Dr. Roscoe of Owens College, Manchester, of the solar spectrum with the spectra of metals. Undertaken with a view of seeing what coincident lines are present in the region between *b* and λ 4660·0, and of examining whether the coincidences can be traced to impurities.

d.—*Work Published (Spectroscopic).*

The following is a list of the papers on the subject of spectroscopic work recently communicated by Mr. Lockyer at the desire of the Committee to the Royal Society.

the sun which have been accumulated since the year 1869, has led Mr. Lockyer to the conclusion that the views generally held with regard to the nature of the solar atmosphere ---views already stated on pp. 10 and 48 of this report— are erroneous; and he has for the last two years been investigating an hypothesis which he first put forward in 1873. This hypothesis supposes that at the temperature of the sun the chemical elements with which we are acquainted here are broken up into finer groups of matter, and that our elements, if they exist at all in the sun, only exist in the higher, and therefore colder, parts of the sun's atmosphere, and that the vertical currents of the sun bring down the formed material to be dissociated in the lower reaches, whence by virtue of its reduced density it reascends to become formed material again at the appropriate heat-level.

A detailed discussion of the manner in which the two hypotheses include the observed solar facts has led him to the conclusion that the new hypothesis has a decided advantage over the old one in this particular:— Phenomena observed both in the laboratory and in the observatory, and on the eclipsed and non-eclipsed sun, which are almost inexplicable on one view follow quite naturally from the other

Mr. Lockyer points out, therefore, that the new view, even if inaccurate, is simple and sufficient as a working hypothesis, and that the main difficulties which beset solar observers when they attempted to harmonize the spectra of the various regions of the sun with the spectra of the various chemical substances visible in their laboratories have now almost entirely disappeared.

The view of the construction of the solar atmosphere to which Mr. Lockyer has been led may be stated as follows. If the atmosphere of the sun were quite tranquil, and if we could see the spectrum of a section of it, we should see it divided into an almost innumerable number of layers, each with its appropriate spectrum. So far from each substance (with some notable exceptions), as determined by a spectral line, extending very far above or below its normal position, it would be confined to one heat-level, and the spectrum taken as a whole would get simpler as we approach the photosphere from without. The metallic elements instead of existing as such in a so-called "reversing layer" resting on the photosphere, are entirely broken up there, and their germs are distributed throughout the atmosphere, the molecular groupings getting more complex as the distance from the region of greatest heat increases. The Fraunhofer

mulates in the higher latitudes till it has sufficient power to occasion a discharge. He regards the earth as analogous to a Leyden jar, the lower portion of the atmosphere forming the dielectric, while the higher portion bears some analogy to the exterior metallic coating of a jar; only, the air in the higher regions is far from being a good conductor, like the tinfoil of the jar, and merely opposes a very much smaller resistance to a disruptive discharge than does the denser portion below. Thus when the difference of tension between the upper atmosphere over one region and that over some other more or less distant region becomes sufficient, a discharge takes place. The opposite electricities, previously bound by induction at the surface of the earth, being thus set free, a redistribution takes place, giving rise to earth currents; and the assemblage of currents partly terrestrial, partly atmospheric, form very nearly closed circuits, and exercise magnetic influence at a distance, giving rise to magnetic disturbances. When the sun is unusually disturbed, the intensely heated portions of matter which come up from below to the sun's surface cause increased radiation, especially as regards rays of high refrangibility, and this, being in part absorbed in the upper regions of the earth's atmosphere, is supposed to render them better conductors, or rather to cause them to oppose less resistance than before to disruptive discharges, facilitating thereby displays of auroræ, and occasioning the earth currents and magnetic disturbances, which on this theory have their origin in auroral discharges.

2.—*Analysis of Fluctuations.*

1. *Long-period fluctuations.*—Professor Stewart and Mr. Dodgson have attempted to analyse the recorded diurnal ranges of magnetic declination from 1781 to 1876. The results obtained indicate that 93 years' observations are not enough to enable us to analyse satisfactorily the long-period fluctuations of this element.

2. *Short-period fluctuations.*—In one of the appendices to this report, page 173, there will be found the description by Professor Stewart of a method of detecting unknown inequalities in a mass of observations.

In the same appendix there will be found an attempt by Professor Stewart to show that certain fluctuations of sun spot activity indicated by a certain specific method of treatment have time-periods and epochs of maximum very nearly coincident with the time-periods and epochs of certain fluctuations of diurnal temperature range at Toronto obtained by a similar method of treatment, the peculiar connexion between

Preliminary Report to the Committee on Solar Physics on the Evidence in favour of the Existence of certain short periods common to Solar and Terrestrial Phenomena. By Balfour Stewart and Wm. Dodgson (Pro. R.S, No. 20, 1879.)

On a Method of Detecting the Unknown Inequalities of a Series of Observations. By Balfour Stewart. Appendix to the report of this Committee, page 173.

Description of an Instrument for measuring possible variations in the Sun's direct Heat. By Balfour Stewart. Appendix to the report of this Committee, page 206.

An Analysis of the recorded Diurnal Ranges of Magnetic Declination with the view of ascertaining if these are composed of Inequalities which exhibit a true periodicity. By Balfour Stewart and Wm. Dodgson (Memoirs of Lit. and Phil. Society of Manchester, March 8, 1881.)

On the Heights of the Rivers Nile and Thames. By Balfour Stewart. ("Nature," January 19, 1882.)

On a Comparison between the Height of the Rivers Elbe and Seine, and the state of the Sun's surface as regards Spots. By Balfour Stewart. (Pro. Lit. and Phil Society, Manchester, March 7, 1882.)

Note on a Comparison of the Diurnal Ranges of Magnetic Declination at Toronto and Kew. By Balfour Stewart and Wm. Dodgson. (Pro. R.S., June 16, 1881.)

Preliminary Report to the Solar Physics Committee on a Comparison for Two years between the Diurnal Ranges of Magnetic Declination as Recorded at the Kew Observatory and the Diurnal Ranges of Atmospheric Temperature as recorded at the Observatories of Stonyhurst, Kew, and Falmouth. By Balfour Stewart. (Pro. R.S., March 9, 1882.)

2. *By Capt. Abney.*

On the Acceleration of Oxidation caused by the least refrangible end of the Spectrum. (Proc. R.S., Vol. XXVII., p. 291.)

Second note on the same subject. (Poc. R.S., Vol. XXVII., p. 291.)

On the Production of Coloured Spectra by Light. (Proc. R S., Vol. XXIX., p 190.)

On the Photographic Method of registering Absorption Spectra. (Phil. Mag., Vol. VII., p. 313.)

matically at the Trigonometrical Survey Office at Dehra Doon, and that that office possesses a sufficient number of employés to carry on continuously for the future the daily photographs of the sun, the taking of which was resumed in December 1879. Since that date there has been a weekly despatch of pictures from India to England. At least two negatives have been taken daily in fair weather, besides "runs," to show the state of instrumental adjustment. Silver prints have been made of all the negatives. A system of despatch in batches has been adopted by which the loss of an entire consignment would leave half of the daily results for any week available as a continuous record.

2.—*Actinometry.*

Professors G. G. Stokes and Balfour Stewart and General Strachey, in their letter of the 11th December 1877 to the Right Hon. Viscount Sandon, M.P., after commenting upon the suitability of Northern India for a series of systematic observations of the sun, remark :—

"Moreover, the clearness of atmosphere, as judged by the eye, which frequently attends great elevations is by no means the only advantage which such situations offer. If the varying condition of the sun does really affect the meteorological state of the earth, it can hardly be doubted that it must be mainly, if not exclusively, through a variation in the amount of heat radiation The existence of such variations may possibly be inferred with greater or less probability from variations in the amount of sun spots or other visible changes; but this could only be as the result of a long continued series of observations, and even then the connexion might remain more or less conjectural. The natural course would be to attempt a *direct* measure of solar radiation by some form of actinometer. The subject of actinometry is not sufficiently advanced to allow us to say at once what is the best form of instrument, and what the best mode of using it. But there is every reason to hope that a thoroughly satisfactory instrument could be devised after some further trial. Whenever the mode of observation shall have been completely settled it will become a matter of the utmost consequence to choose a station of great elevation, where as much as possible of the lower strata of tha earth's atmosphere shall be got rid of. It is only in low latitudes that this advantage can be secured without going above the region of human habitations. This consideration again points distinctly to Northern India as a locality eminently suitable for continuous observations. It

at the latter place at all events the observations are confined to a restricted part of the spectrum.

We recommend that communications should be opened with observatories where such work would be likely to be prosecuted, suggesting simultaneous observations on a definite plan for a limited period, say for the next three years; and that the reduction of these observations should be undertaken at South Kensington.

In this way we believe results of the highest importance in their bearing upon solar theory would be obtained in the shortest possible time, and with a minimum of expense.

We now come to another part of the inquiry that which refers to combined laboratory and observatory work, to the comparison of lines seen in the spectrum of the sun with those seen in the spectra of terrestrial bodies.

Here, unfortunately, the work is almost entirely confined to South Kensington, where its progress is very slow, partly in consequence of the limited facilities, partly in consequence of the bad climate.

As such work is necessarily the keystone of the arch which may unite celestial and terrestrial chemistry, we recommend that certain steps should be taken to accelerate the rate of progress, and we have indicated these to the Science and Art Department.

(2.) *Solar radiation.*

The best proof of solar variability would be the direct one given by an actinometer or instrument so constructed as to measure with accuracy the amount of radiant energy given out by the sun, but as yet hardly any such observations have been made.

We attach great importance to the use of such instruments in the future, and we are in hopes that in India and elsewhere much information may soon be obtained by their means.

But even assuming the possession of a perfect actinometer there are considerable difficulties in the way of obtaining by its means the true solar radiation.

Allowing, for the sake of argument, a variability in the sun's power, it seems probable that during those years when the sun is increasing in power the quantity of aqueous vapour suspended in the air should also continue to increase. But it is known from the researches of Prof. Tyndall and others that this would imply a continually increasing atmospheric absorption, which would stop each year an increasing proportion of the

It should here be remarked that, by comparing with a standard certain definite regions of the spectrum unabsorbed by any of the constituents of the earth's atmosphere, we might be able to ascertain any variation in the quantity or in the quality of the true solar radiation.

We recommend that the heat actinometer by Prof Stewart, the chemical actinometer by Prof. Roscoe, and the supplementary instrument by Mr. Winstanley be established at Lé, it being understood that the Indian Government is ready to bear the expense of the instruments and of the observations with them.

We recommend also that the suggestions of General Strachey already mentioned should, if possible, be carried into effect.

(3.) *Influence of the State of Sun on the Meteorology of the Earth.*

While observations of atmospheric and of underground temperature appear to give evidence of a fluctuation in the temperature of the air having the same period as that of sun spots, yet on the whole they appear to show that a maximum of sun spots corresponds to a low and not to a high temperature.

But if we bear in mind that temperature is an exceedingly complex phenomenon, and that an excessive rainfall generally produces a low temperature, we cannot receive this as evidence tending to show that the sun is least powerful at epochs of maximum sun spots. It seems possible, however, that something might be done by confining ourselves to short-period inequalities, if the existence of such inequalities should be made out with tolerable certainty.

Professor Stewart has pointed out the apparent existence at Toronto of fluctuations of diurnal temperature range, having periods very nearly corresponding to those of sun spots, and of a nature which leads him to infer that a maximum of sun spots is associated with a maximum of solar power. We think that this investigation might be extended so far as to take three or four prominent solar inequalities, and see whether they correspond to similar inequalities of temperature range. This would appear to be a method likely to show if there be any real connexion between sun spots and terrestrial meteorology, waiving for the present the question of true periodicity in such inequalities.

With respect to rainfall, while the observations appear to indicate that at certain localities we have a maximum amount of rain about the time of maximum sun spot frequency, yet

(4.) *Influence of the State of Sun on the Magnetism of the Earth.*

There can be no doubt that the diurnal range of the earth's magnetism is greatest when there are most sun spots, and that on such occasions there is likewise an unusually large number of magnetic storms with their accompaniments in the form of earth currents and auroral displays.

There are also strong indications that the fluctuations in the diurnal ranges lag, as a rule, in point of time behind the solar influences which produce them.

This would most naturally lead us to suppose that these diurnal magnetic effects are not directly caused by solar magnetic influences, but indirectly by solar radiation.

Again, the large amount of variation in the declination range, which increases nearly in the ratio of *two* to *three* between times of minimum and times of maximum sun spots, might perhaps induce us to locate the solar influence which brings about this result in the upper regions of the earth's atmosphere where there is reason to think inequalities in solar radiation would be particularly felt.

In order to investigate this subject we recommend: First, a more extended comparison of the declination curves at Kew and Stonyhurst, after the manner of the preliminary comparison already referred to in this report. Secondly, a more extended comparison between the meteorological and the magnetical weather of the British Isles, after the manner of the preliminary comparison also referred to in this report. Thirdly, a more extended investigation with the object of deciding whether declination range inequalities do really appear to travel from west to east as far at least as phase is concerned.

Finally, with the view of carrying out the valuable suggestions of Senhor Capello, contained in a letter published in an appendix to this report, page 239, namely, that the directors of observatories possessing self-recording magnetographs should arrange together some uniform plan of utilising the curves produced by such instruments, we recommend that communications should be entered into with the Kew Committee of the Royal Society in order to concert some method of action in this respect.

in connexion with these observations is the provision of a competent observer. In a report by Professors G. G. Stokes and Balfour Stewart and General Strachey, presented to the Lords of the Committee of Council on Education (dated 11th December 1877), after pointing out the suitability of Lé for observations on solar physics, it is suggested that an intelligent sapper trained in England should take the observations. On this point, Mr. Ney Elias observes :—

"As regards a person to take the observations, an European would certainly do better work than a Native. But it would depend a good deal on the man selected whether he would be able to get on here or not ; if he chanced to be a quiet-going individual, who would not mind the solitude, the rough living, and the cold, &c, I fancy he might manage very well. You will easily see that in a place like this it would be most awkward to have a troublesome or disreputable European. But, on the other hand, there would be no question about the efficiency and trustworthiness of the work if done by a trained European, while the present observatory would also benefit, and might even be extended, if he were made chief observer, in addition to his duties with the actinometer. Again, if I were to be transferred, or were to be absent for any time (as I often am), you would still be able to rely on the work being carried out."

"There is no doubt that, as Mr. Ney Elias well points out, an uneducated European would be exposed to some temptations, arising from the solitude and the cold ; and on this account I do not think it would be advisable to count on the employment of an European for an indefinite period at so remote and inhospitable a station as Lé. But there would be so many advantages in having the work started and carried on, say, for a couple of years by a well-trained European, that I think the suggestion offered by Professors Stokes and Stewart and General Strachey should be adopted, and since an assistant would be required both for the actinometric work and the meteorological observatory, a well-selected English-speaking native of Upper India should be sent up with him, and on the return of the latter to India, would have become competent to carry on the work in his place.

"There is another reason why I am disposed to adopt the suggestion that an observer should be selected and sent out from home. In a subsequent report of Professor G. G. Stokes, adopted by the Committee on Solar Physics, it is recommended that, in conjunction with the observations of the actinometer, those of an instrument devised by Mr. Winstanley and modified by Captain Abney, which gives

18. Kaemtz's Meteorology. On the Aurora Borealis, its Phenomena and Laws. By Elias Loomis. Smithsonian Report for 1865, page 208.

19. Same as 10.

20. W. H. Barlow. On the Spontaneous Electrical Currents observed in the Wires of the Electric Telegraph. Philosophical Transactions for 1849, page 61.

21. C. V. Walker. On Magnetic Storms and Earth Currents. Philosophical Transactions for 1862, page 203.

22. J. Lamont. Poggendorff's Annalen, Vol. LXXXIV., 1851, page 572.

23. Same as 13.

24. R. Wolf. Comptes Rendus, Vol. XXXV., 1852, page 704.

25. A. Gautier. Bibliothèque Universelle, Archives. Vol. XX., pages 177 and 265.

26. Same as 10.

27. W. Ellis. Philosophical Transactions for 1880, page 541.

28. E. Sabine Philosophical Transactions for 1847.

29. J. A. Broun. Trevandrum Observations, Vol. I.

30. B. Stewart. Proceedings of the Royal Society, March 9, 1882

31. Same as 27.

32. B. Stewart and M. Hiraoka. Proceedings of the Royal Society, Vol. XXVIII., page 288. Also B. Stewart and W. Dodgson, Vol. XXIX., page 303, and Vol. XXXII., page 406.

33. W. Sidgreaves and B Stewart. Proceedings of the Royal Society, Vol. XVII. (1869), page 236.

34. B. Stewart. Monthly Notices of the Astronomical Society, Vol. XXX., page 34.

35. J. Baxendell Memoirs of the Literary and Philosophical Society of Manchester, 1871–73

36. E. D. Archibald. Barometric Pressure and Sun Spots, "Nature," May 8, 1879; J. A. Broun, Sun Spots, Atmospheric Pressure, and the Sun's Heat, "Nature," November 7, 1878; C. Chambers, Meteorology of the Bombay Presidency; Eliot, Report on the Meteorology of India, in 1877; S. A. Hill, Atmospheric Pressure and Solar Heat, "Nature," March 13, 1879.

37. H. F. Blanford. On the Barometric See-Saw between Russia and India, in the Sun Spot Cycle, "Nature," March 18, 1880.

38. F. Chambers. Abnormal Variations of Barometric Pressure in the Tropics, and their Relation to Sun Spots,

meteorological work, which needs continuity of skilled supervision, should suffer no interruption. His Excellency in Council has, therefore, decided to apply to the Secretary of State for the services of a duly qualified officer.

"Mr. Blanford further recommended that a trained European should be sent up to Lé to start these observations and instruct the permanent Native observer attached to the observatory. The Solar Physics Committee have volunteered to select a sapper of the requsite qualifications in England, who will be there instructed in the use of the Winstanley instrument as an adjunct to the actinometer. The term of his engagement should, it is proposed, be for two years, at the end of which the native assistant observer at Lé will probably be able to conduct the work without further supervision. The pay of the sapper is estimated at Rs. 250 per mensem, and that of the Native assistant Rs. 150, or an annual expenditure of Rs. 4,800. The cost of the Winstanley instrument would be in addition to this."

On receipt of this communication the India Office requested the Solar Physics Committee to recommend a trained sapper capable of conducting actinometric observations, for employment at Lé for two years, on a monthly pay of Rs. 250, and inquired the probable cost of the "Winstanley instrument." And the Committee at once arranged that inquiries should be made for fit and available men, and they subsequently approached the deputy Adjutant General, Royal Engineers, on the subject. The War Office in reply stated that a suitable non-commissioned officer of Royal Engineers could be named for observing at Lé, on application being made from the India Office, the man being transferred to the Indian establishment during the time of his employment, and the India Office were informed accordingly.

3.—*Earth Thermometers.*

The Committee in the year 1879 explained to Sir George Airy the work which they proposed to undertake, and expressed their hope that they might rely upon his cooperation In his reply the late Astronomer Royal, whilst reviewing the remarks of the Committee, directed special attention to the use of earth thermometers in the following terms:—

"In the report, dated 11 December 1877, Article 9, allusion is made to the importance of direct measurement of the sun's radiation. I venture to remark that experience on the broad scale leads me to believe that this may be

photograph were taken when the sun was pretty low that the effect of refraction would be sensible

The most convenient process is next to calculate the polar co-ordinates (or in other words the distance from the centre and angle of position) from the rectangular co-ordinates Let S, E, P be the centre of the sun, the earth regarded as a point, the spot The radius vector inferred from the rectangular co-ordinates is very nearly that belonging to the orthogonal projection of S P on a plane through S perpendicular to S E. A very minute correction, which depends on the non-parallelism of S E, P E, and which can be made at once by inspection, suffices to reduce it to the orthogonal projection. The distance from the centre referred to the scale radius = 1 is the sine of the inclination of S P to S E

The time of taking the photograph being known, we get the sun's longitude L from the Nautical Almanac, and thence the inclination, I, of circles of latitude and declination passing through the sun from the formula

$$\tan I = \tan O \cos L,$$

where O is the obliquity of the ecliptic The fiducial line, which applied primarily to the equator, is hereby referred to the ecliptic, and by applying to this angle the angle of position, which forms one of the polar co-ordinates, we get the inclination of the plane E S P to a plane through E S perpendicular to the ecliptic. Two formulæ equally simple with the above then give the heliocentric latitude and longitude of the spot.

The other method, which I should prefer, is to measure at once the polar co-ordinates, using a microscope of very low power with cross lines The microscope slides along a horizontal rest, graduated so as to read with a Vernier, say to 0 001 inch, or else 0·001 of the average radius The rest and microscope are supported on a horizontal circle graduated to degrees, with a Vernier reading to 5′ and by estimation to 1′ The plate is laid on a support underneath this, which is provided with slow motions in two rectangular directions for centering

If readings taken by applying a scale to the photograph and estimating the fractions of intervals be deemed sufficiently accurate, a glass scale graduated by concentric circles and radial lines might be used instead of the rectangular network. The estimation would be a little more troublesome and less accurate, but the trouble of subsequent reduction to polar co-ordinates would be saved.

We should thus get with very little trouble the heliocentric places of the various spots in each photograph, referred to the celestial sphere But we should also wish to know the places referred to the sun itself, treated as if it all revolved together like a solid globe, which Carrington has shown to be only approximately true This might be done by calculation, using Carrington's elements. But the calculation is considerably longer than those hitherto mentioned, and it would be desirable to avoid it by a graphical process

The simplest process of this kind that I have thought of, and one which would, I believe, give the reduced places even more accurately than is required considering errors of observation, is to use a large globe. This would have the further advantage of presenting to the eye the combined results in a digested form. The globe should be provided with two axes at an inclination of 7° 15′ The meridian circle should be graduated to degrees, better perhaps sub-divided to 20′ The globe is a blank, save as to two

I think, open to much question And it is to actinometric observations that we must look for determining the very important question of that variability."

4.—*Photoheliographs.*

The Government of India having, through the India Office, called upon the Solar Physics Committee for an expression of their opinion as to the advisability of taking photographs of the sun's disc upon a larger scale than was then feasible, the Committee pointed out the alterations which would be necessary to enable such pictures to be taken with the photoheliograph then in use in India. The India Office in reply sanctioned an expenditure of 10*l.* to effect the necessary improvements, and requested the Committee to give instructions for carrying out the work.

In consequence of the modification of the secondary magnifier it became necessary to alter the camera, of which three modifications were tried, the last resulting in some very satisfactory pictures, specimens of which were forwarded to the India Office for transmission to India During the time that these experiments were in progress the Government of India reverted to the doubts which had been raised as to the scientific value of the small sized pictures of the sun produced by their photoheliograph as compared with the large photographs taken in France by Monsieur Janssen, and having expressed their opinion that a larger and better instrument than that in use at Dehra Doon should be made available for the purposes of carrying on solar photography in India, the India Office requested the Solar Physics Committee to state their opinion as to whether the contemplated alterations in the then existing instrument would make it fully available for the purpose desired or whether another instrument should be provided. In the latter case it was requested that the Committee would specify the description of instrument which they recommended and approximately estimate its cost.

The opinion of the Solar Physics Committee, which was communicated to the India Office, was as follows:—

"We are of opinion that it has been established by our experiments that for a sum of about 25*l.* a photoheliograph, similar to the one in use at Dehra Doon, can be made to give pictures 8 inches in diameter, at least as well as it now gives them of 4 inches diameter. This sum is required to provide the instrument with a new secondary magnifier and a brass extension of the tube, together with a camera for

the catalogue The letters br in connection with an Ely picture mean that the glass is broken; the picture, however, may not be without value, There are cases in which the exact times of the Cambridge (U.S) pictures are not given. Professor Pickering, however, says that these can be furnished when required

In the Greenwich list those pictures for which exact dates are given have already been reduced, and the results published by the Astronomer Royal In most of those cases where the exact date is left blank there are no spots on the sun's disk. If required the exact time can be furnished by the Astronomer Royal.

8 We subjoin a specimen of the method of recording sun-spot observations suggested by the Solar Physics Committee

SPECIMEN FORM OF METHOD PROPOSED FOR RECORDING SUN-SPOT INFORMATION.

Date.	G. M. T of Sun-picture (Noon=50).	Where observed	Adopted number of group.	Heliographic position of mean centre of group		Apparent distance from visual centre of Sun, of mean centre of group (radius =, 1).	Area of group in millionths of visible Hemisphere (umbra *plus* penumbra).
				Longitude	Latitude.		
1864							
June 20	·49	Kew	564	25°·3	+19·2	0 426	37
,, 24	·60	Kew	564	24 8	+18 9	0·920	359
,, 27	60	Kew	565	306 2	− 7·2	0 179	155
,,	,,	,,	566	198 2	+21 5	0 969	211
,, 30	·66	Wilna	566	199 4	+20·8	0·601	132
,,	,,	,,	(6)	299·5	+18·4	0 883	108

Remarks on the above.

(*a*.) Being merely intended as a specimen, the numbers are imaginary.

(*b*) Groups have been numbered in accordance with the Kew catalogue, while that series lasted, and, after its discontinuance, in accordance with the catalogue of Greenwich.

(*c*) Whenever, owing to blanks produced by bad weather, a spot which has been recorded at some other observatory cannot be identified with any one in the Kew or Greenwich catalogue, it receives a number which is enclosed in brackets, in order to distinguish it from the regular numbering. Thus in the above (6) means that six such groups have occurred in 1864 up to June 30, which have neither been identified with Kew or Greenwich groups, nor with each other.

(*d*) The object of the Committee being to obtain physical rather than precise astronomical information, the measure of accuracy need not in any case go beyond that which records the mean heliographic position of a group to the tenth of a degree, and of the time to the hundredth of a day; and with regard to past work, the Committee will be content with a somewhat lower standard when this measure is not easily attainable.

(*e*) In the areas recorded, allowance is made for foreshortening.

(4.) *Instruments and Observatories.*

1.—*Instruments originally at the disposal of the Committee.*

The instruments at the disposal of the Committee at the date of their appointment in 1879 were as follows:—

1. A 6-inch telescope equatorially mounted with declination, and right ascension circles, made by Cooke, of York, the property of Mr. Lockyer. To this instrument two spectroscopes can be attached. One is a grating-spectroscope, the property of Mr. Lockyer, with a grating made by Rutherfurd, having about 17,280 lines to the inch; and the other is a spectroscope with seven prisms of 45° made by Browning, the property of the Royal Society.* This instrument is in a square canvas hut with a sliding roof.
2. A $3\frac{3}{4}$-inch achromatic telescope made by Cooke, of York, the property of Mr. Lockyer.
3. $9\frac{1}{3}$-inch Browning-With mirror with tube complete, the property of Mr. Lockyer.
4. A siderostat, made by Cooke, of York; this is the property of the Royal Society,* and is lent to Mr. Lockyer.
5. A small induction coil, the property of the Royal Society,* lent to Mr. Lockyer.
6. A Siemens' dynamo-electric machine and lamp, lent by Dr. Siemens, F.R.S., to Mr. Lockyer.

6A. An enlarging camera, the property of the Royal Society, lent to Mr. Lockyer.

6B. A lathe.

7. A 4-inch telescope with object glass corrected for the chemical rays by Cornu's method, lent by Dr. De La Rue.
8. A short focus photographic lens of 6 inches aperture and smaller lens. These are the property of the Science and Art Department.
9. A spectroscope, the property of the Department, used with the Rutherfurd grating; the scale is observed by a second telescope clamped above the observing telescope.
10. A small heliostat for use with the spectroscope. The property of the Department.
11. An enlarging camera, lent by Dr. Warren De La Rue.

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* As trustees for the Government, the instruments having been paid for out of the Government Grant.

DAY.	JAN	FEB	MAR.	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV.	DEC.
1		780.1								882.6	852.6	1458.7
2		630 1	774.3		1146.5	888·3		918 3		1014.6	672 5	
3				336.2	1428.6	858 3				570.5		
4			522 2		2322.9		312.3				321 2	1128 6
5	0.0	270.1		1236 3						51.3		
6	0 0			810.3	906.5	1350.3					1200.3	
7	0.0			690 2						54.3		
8				648.3			12 2		1332 1	936 3		636.3
9	0.0	426.2	408.2	804 5	552.4		522.2			900 3	1230 5	
10	0 0				738 3	750.2						912.4
11		120.1	648.2	678 5		690 2	1266.4		1971.6	1080.1		810 5
12	24.1						2034.5					
13	48.1	144.2	300.1	828.4	330 4		1674.5				1950.8	
14	60 1	258 2		1104.5		912.3				768.1	2316 9	
15	18.1	222.2		1800 5	804 2				1314·5	1008·6		
16	0 0				831 2							
17	0.0	42 2			510 2					1020.4		
18	0.0		60.1		480.2	36 1				858.6		
19					408.2	0 0			1020.5		1182.7	
20	0 0		30.1	456 3	348.2	360 1						
21	24.1				420.2	126.1	1080.5		1968.9	1056.9		978 4
22	0 0	564.2	0.0						3174 10	942.10	1398 7	
23	0 0		0 0	600 3								
24	0 0						414.2		1776 7	1392.9	1032.6	
25	24.1	0 0	42 1		720 1	576 3						
26									846 7		1188.6	
27		84.1			0.0		1008.3		684.6			
28		606.3		810.3	0.0						1170.5	
29	60.1	——	72.1				1002 4		828.5		960.5	636.3
30		——	0.0	522 4		432.3			1266.7	804.9		
31	492.1	——	72.1	——	234.2	——	810.4		——		——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

3.—*Instruments lent by the Astronomer Royal.*

The Astronomer Royal has also placed the following instruments at the disposal of the Committee.

1 A photoheliograph for taking solar pictures 4 inches in diameter, made by Dallmeyer, together with the hut in which it stands. This is now dismounted, the stand having been used for the Eclipse Expedition, and subsequently transferred temporarily to the Transit of Venus Committee.

2. 6-inch equatorial, by Troughton and Simms, with hut. This also has been temporarily transferred to the Transit of Venus Committee.

4.—*Large Photoheliograph.*

At the commencement of their labours, the Committee decided that one of the first things to be done was to take direct pictures of the sun not less than 12 inches in diameter. A 6-inch object glass of a focal length of 9-feet, and corrected for the line G, was obtained from Mr. Dallmeyer; this was mounted on a rough tube, and a 10 by 12-inch camera was attached. A parallactic ladder was constructed, and some trial plates taken; the pictures obtained being very satisfactory. A 15-inch by 15-inch camera was attached, and the instrument was mounted upon a more rigid ladder. Some good pictures were obtained, but as opportunities were frequently lost, owing to the necessity of moving the instrument in and out of cover, it was decided to have it mounted equatorially. This was done by Cooke of York, and the instrument was erected and pictures taken regularly on all favourable opportunities.

In March 1880 a letter was received from the Indian Government, suggesting that it would be advisable to increase the size of the pictures being taken in India. As the Indian Government were anxious to take large pictures without further delay, the Committee suggested that they should transfer their instrument to the Indian Government. This offer was accepted, the Indian Government undertaking to pay for the construction of another. The instrument was accordingly transferred to the India Office, and has now arrived in India.

The new 6-inch photoheliograph is in course of construction, and will be finished in a month or so.

DAY.	JAN	FEB.	MAR.	APR.	MAY.	JUNE	JULY	AUG	SEPT	OCT	NOV.	DEC
1				324·3		108 1	618 4	1056.8		1272 7		
2	1104 5		576.4		168.2	168.3						
3					582 3	636.4		1320.5	1440 5			
4	996 8	1746 5	378.4			822.3	1260 7	1218 5		672 6		180 2
5	162.7				114 3		1182.9		2010 6			
6	600.6	1434.5		348.3	630 3		882 8			246.3	294.2	
7			276.3		720.3	612 3	870.7	1164.6	1116.5			
8	858.6			396.3	594 4	1086 3	918 8		1830.5		510.5	
9			222.5	474 4	450.2	792 1		1080 6	780.4	534.5		336.3
10	348 3		750.6	438.5	894.4		390 6	756.7	870.4	186 5	828.6	570.1
11	756.5	576 5	1410.6	840.3			792 6	990 5		420 6		108.3
12		1251 5	858.8		552.3	510 2	1026 6		531 3			
13		501.5	1284.5	492.4	582 3		798.9				816.6	
14	186.3		1320 6	516.1	861.4	930 2		750.5	708 3	816 1		
15		918 5	978.7		906.1	924.3	282.4	624.6	918 1	1014.4		
16	876.5			606 1		510 2			540 1			
17	816.5	1188 6		678.3		750 3	360 2			918 1		
18	1038 4					552 2	546 3			1218.5	612.6	
19		936.4					276.3		912 8	1716.6	552.6	444.2
20		918 5		1356.4	840.3	810 2	900.4		1752 9	1380.6		
21		930.7	810 5		720.2	660.5	510 2		2640 8			
22				456.2			288 2					
23	1464.8			564·4		858.5	360.1			768.5	312.2	306.3
24					456 3		768 3		1038 9		576.3	
25		1488·9			756.3		378.3	1500.7	1140.7			
26					504.3	180.3	252.3	1290.7	1158.8		300.2	630.1
27		1068 5					1158.5				321.2	
28				390.3	900.1	180.2			2202 12			
29	1620.5	—	108.3		210.2	108 3	582.7	122.10	2136·8	198 1		528·7
30		—	114.3		102 3	330.4		3720 10		240 3		
31		—	318.2	—	186.4	—	1014.7		—		—	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

and a hut for the large photoheliograph, with a revolving roof, have been constructed by the Works Department of the Museum.

8.—*Present Condition of the Buildings.*

1. The 6-inch equatorial belonging to the Indian Government is in a hut with a revolving roof between the Western Exhibition Galleries and Queen's Gate, near the entrance to the Horticultural Society's Garden.

2. Mr. Lockyer's 6-inch equatorial is in a canvas hut with a sliding roof to the north of the other equatorial.

3. The siderostat is in a hut running back on a tramway in the Horticultural Gardens.

4 The small photoheliograph hut is also erected in the Horticultural Gardens.

5. The hut for the large photoheliograph and the photographic studio are erected on the vacant ground behind the post office in Exhibition Road.

All of these observatories are in a good state of repair.

(5.) *Sun Spot Catalogue.*

Among the duties of the Committee has been the collecting together of information regarding the sun which exists at present in a scattered state and is not easily accessible. With this object a catalogue of the sun pictures, taken by various institutions and private observers, has been already prepared; and this forms an appendix to the report of the Committee, page 77.

In this catalogue, written jointly by Mr. Warren De La Rue and Professor Stewart, will be found a dated list of known sun pictures to the end of 1877, which may be regarded as nearly complete, if we except some observations made by Dr. C. Hornstein, and certain pictures taken by Senhor Capello, which have since been brought before the notice of this Committee. This catalogue contains in addition the total spotted areas, as well as the number of groups, for each day on which the late Hofrath Schwabe made a picture of the sun. It contains also a description and specimen of the way in which it is proposed ultimately to embody information regarding sun spots.

On the publication of this catalogue it was considered desirable to communicate again with the directors of those observatories where solar work is carried on. The following

letter was circulated by desire of the Committee in July 1881:—

Science and Art Department,
London, S.W.,
13th July 1881.

SIR,

ON the 31st December last the Committee appointed to advise on the methods of carrying on Observations in Solar Physics had the honour of addressing you on the subject of their work, and the catalogue of sun pictures referred to in that communication has since been forwarded to you.

As one of the objects which the Committee consider very important is to bring together the Solar information which at present exists, they are very anxious to know whether it will be in your power kindly to assist them in this task by making very simple measurements of the areas and positions of sun spots from the pictures which you possess, such as are specified in the catalogue of sun spots already mentioned. The number of observations sought would be reduced to a minimum, while the amount of precision required for the purposes of the Committee would not be very great. If you consent to afford your valuable assistance in the manner thus indicated, the Committee will be glad to enter into communication with you, with a view to discuss details.

This letter was sent to the following:—

Dr. Bredichin, the Observatory, Moscow, Russia.
R. T. Ellery, F.R.S., Observatory, Melbourne, Australia.
C. Meldrum, F.R.S., Observatory, Mauritius.
Professor Pickering, Observatory, Cambridge, U.S.A.
Dr. Smysloff, Observatory, Wilna, Russia.

The replies received by the Committee to this circular are such as to evince the greatest readiness in all these solar observers to aid the Committee as far as they possibly can. In consequence of this valuable co-operation it is expected that the labour of collecting and publishing the solar information which at present exists will be materially reduced.

(6.) *Measurement of Sun Spots.*

The Committee have given great attention to the subject of the reduction of sun-spot observations with a view to being prepared to deal with the large number of daily photographs to be expected when the various observatories which have already promised co-operation are in full work.

Their first idea was that there were several graphic methods which would readily and rapidly give the data necessary for the Committee's needs, it being understood from the first that several purely astronomical problems requiring elaborate calculation connected with the sun should be left out of their consideration, and should be dealt with at Greenwich.

When, however, the Committee was strengthened by the appointment of the Astronomer Royal as a member they learnt that the determination of positions of sun spots at Greenwich was about to be simplified by giving up an attempt at accuracy which was, as a rule, not capable of realization in consequence of the indefiniteness of some of the phenomena.

At the same time the Astronomer Royal offered to undertake the daily determination of the positions and areas of all spots. This offer has been accepted by the Committee, and already some of the Indian photographs for dates subsequent to 1st January 1882 have been forwarded to Greenwich for reduction.

There remains then for consideration the question of the measurement and discussion of photographs anterior to this date which have been received from India and elsewhere but have not yet been reduced.

The arrangements at Greenwich will not allow of this back work being done there. We would, therefore, propose that an instrument similar to that now in use at Greenwich should be obtained from Messrs. Troughton and Simms, and that the reduction should be performed in the same manner as for 1882, but should be limited to those photographs only which fill gaps in the Greenwich series.

We would propose that the instrument though of the same form and arrangement as that now in use at Greenwich should be constructed of such a size that the 8-inch and 12-inch pictures which we shall subsequently obtain from India can be measured on the same system as that at present employed for the smaller pictures.

The Astronomer Royal has expressed his willingness to obtain and train an observer for this work; the expense would in all probability not exceed 4*l.* or 5*l.* a month.

(7) *Measurement of Solar Radiation.*

1. *Heat Actinometer.*

An actinometer constructed by Professor Stewart was at an early period brought before the notice of the Committee.

DAY	JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY.	AUG.	SEPT.	OCT	NOV.	DEC.
1			600.2	174.3	492.2	456.4	192.3	36.2	1380.8		1296.9	
2				234·4	282.4	498.5		30.3		1776 11	1542.9	
3	780.4				330.4		12.1	120.4				
4					276.3	156.2		342.3		2214.8		
5	426.3				318.3	330 4	120.3	384.6	1374.8		1974.7	
6				492 3	360.3	702.5	126.3	258.7	1074.8		1656.9	978.9
7				492.2	522.3	612·5	120.2	546.8			1260.10	
8				1110.3	456.2	282.4		486.7	660.5		1602.10	1158.6
9			1236.8		630 6	588.6	12.1	384.5		1956.11	2340.9	951.7
10		222.1	864.5	660.2	768.6	816.4	78.3	624.5				852.6
11	372.2	270.1	2370.6		1050.8	720.4	78.3	600.3	1296 6	1788.9	1551.6	1041.5
12	180.1	1740.3	1548.6	816.4			54.3	1758.5	1194.8	1941.9	1788.5	930.4
13				672.4		768.4	108.3	2052.5		2142.9		1086.6
14		1950.3		1200.4	108.3	696 4	474.3	2478.8	1950.7	1500.8		756.4
15	90.1		2298.8		390.3	1410.3	438.3	2826.10	1308.5	1260.7		
16					294.4	1290.3	906.4	2622 11		1512.9		768.3
17			1974.9			1146.4	930.5	2436 11		1806.9	1056.5	756.5
18			1968.11	282.3	474.4	1458 4		1902 10		1488.7	1476.6	1212.5
19		1476.5	1386 11	384.1		1308.4	1212.4	1878.9	2514.7		1041.4	1134.6
20	36.1		1242.9	336.2			870.4	1674 6	2832.7	1812.9		1638.6
21			918.5	270.1	330.5	1416.5	1650.4	2634.7	2790.7	1872.6	156.3	
22		1560.3	912.5	330.1	324.5		1392.6	1824.7	2778.8	1770.6		
23		840.2	990.4		390.5	1440.6				1584.7	1308.5	
24	900.4	600.1	600.3	936.3	396.4	1122.6		1914.8	1854.8	1584.9	1308.6	
25		720.1	528.3	486.2	276.3	900.5	846.5				1686.8	
26	1812.5			108.2	552.4		660.5			1086.8	1710.7	
27				132.2	558.4	678.6			1236.5	1698.6	1938.9	
28		720.2	624.4	168.2	438.3	924.5	402.1	1560.9			1998.10	
29	2220.4	——		150.1	522.5		144.1	1578.8				
30		——	120.3	90.1		234.5	48.2	1590.7			2232.9	
31		——		——	594.5	——	48.1	1362.6	——		——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

Lock when the tidal water has all drained off. This record extends from the beginning of 1860 to the end of 1880.

At present it is impossible to deduce from these records the volume of water which passes in unit of time across a section of these rivers; nevertheless the results give us a good deal of information, for we may be sure that an increase in depth denotes an increase in the volume of the water carried by the river, and a decrease in depth a diminution of the same.

Results deduced from these records by Prof. Stewart have been communicated to "Nature".[53] These results, when put into a graphical form, have led to the following conclusions:—

(1.) There is a considerable likeness between the Nile curve and that for the River Thames.

(2.) There appears to be a maximum in these curves at or somewhat after the date of maximum sun spots, but they have more than one maximum for one sun spot cycle.

In order to confirm these results Prof. Stewart has reduced in a similar manner the heights of the Rivers Elbe and Seine.[54] He has split the whole number of observations of these heights extending over a century for the Elbe, and embracing nearly a century for the Seine, into two equal portions, and he finds that each of these portions for each of these rivers indicates a maximum height shortly after the sun spot maximum, and also another subsidiary maximum, not far from the time of minimum sun spots.

Thus the chief difference between these continental rivers and the Rivers Nile and Thames is that in the latter the second maximum is more developed, and is not subsidiary as it is in the former.

(9.) *The Eclipse of May* 1882.

The importance of observations of this eclipse was brought before the Committee by Mr. Lockyer in May 1881. Mr. Lockyer and Captain Abney were then requested to draw up memoranda relating to the work which, in their opinion, should be done.

These memoranda are as follows:—

"The total eclipse of the sun which takes place in May next year will be visible in such an accessible region that it is to be hoped that the precedents of 1860, 1870, 1871, and 1875 will be followed and steps taken to secure observations, the more especially as the eclipse will happen somewhat near

DAY.	JAN.	FEB.	MAR.	APR.	MAY.	JUNE	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.
1		1362.6		474.2	1200.4	816.5	360.2	204.3		822.3	546 3	438.4
2	294.3	1182.6	444 5	378.2	1236.6	1020.5	360.1			462.4		66.4
3	324.4			744.3	828.5	594.2	360.1	684.3			288.2	
4			498.3		618.4	570.2	210 1	450.2	1152.5	18.1		516.4
5	420.3	2028.11	456.3		1092.5			672.3	900.1			
6			582.3	402.3	1242.5	468 2	264.2	612.3	1170.1	420.1	318.1	
7	582.5			480.3	1734.6	660.1		456.3	906.5	18.2		
8					1230.5		324.2	564.1	822.4	372.3	276.4	174.3
9				396 3		900.2	492.2	924.3	720.4	618.3	738.3	84.2
10		1188.5	1302.5		1110.5	510.2	480.2	912.4		858.3		
11		1080.5	1716.7		1440.6	444.2		318.3		378.2		282.4
12	990.6	882.5	1170.5		852 6	540.2		348.3				
13	1452.5	1224.5	798.5			186.2	792.3	318.5	708.4	456.3		
14	678.3		642.4			690.3	570.3	390.5		762.3		
15	570.2	1074.5	678.4	1560.6	1164.5	474.3	720.3	498.4	636.5	504.3	354.2	
16		990.4		666.5	336.4		714.3	510.4	390.3		330.2	1062.4
17		1308.5		816.5	420 3	558 3		282.4	366.3			
18		1320.6	894 5	798.4	702.4	564.4		228.4	786.5	570.3	870.3	
19			930.4	672.4	210.2	312.4	312.2	168.3		918.3	948.3	
20					180.2	942.7		588.3		1020.3		1404.5
21	270.2	858.6			750.4	702.6	390.2	366 3		720.3	1272.4	1332.4
22			1242.4	750.3		672.4	252.2	390.2	1272.5	1170.4		1194.6
23	240.3	1140 7	1374.4	708.3	366.3		390.2	582.4	1434.5		546.3	
24		786.6		510.2	492.3	780.3	192.3	498.5				
25	432.3	768.5	750.3		378.2	1002.3	192.2					
26							180.1	918.5	570.3	462.4	312.4	
27	546.2	912.7	780.4	720.3	510.2		270.1	1008.5				
28	522.3		138.2		426.3	288 4	360.2					
29	1020.6	—		402.2	390.2			708.5		192.2		912.3
30	1650.6	—	882.3	786.3		936.2	312.1	1434.7		726.3		
31	1986.6	—	696.3	—	354.4	—	264.1	1128.5	—		—	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

DAY.	JAN	FEB.	MAR.	APR.	MAY.	JUNE	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.
1	780.2		150.1	648.3		480.2	0.0	270.2	348.4			12.1 R 50
2				240.2		630.2		330.2	774.3	600.2	630.3	72.2 R. 48
3	1152.3	60.2		606.4	420.1	270 1	354.2	294.3	642.5	480 2		252.2
4	870.3		150.1	918 4		168.2	384.2	516.3	561.4	540.3		
5	480 3		0.0				354.3	474.1	276.2	672.5		
6	162 2		0.0	804.4	450 1	462.3	492.4	360.4	408.3	1116.5		
7	96.2		36.1	714.4		522.3	930.4					18.1
8				276.2	234.2	600.3	894.4	660.4		846.5		R. 60
9	312 2			156.2	360.1		618.3	606.4			300.2 R. 49	R. 49
10	570.2	342.3	108.1	96.2	504.2	1032.3	540.3	612.4	378.3	432.3		426.2
11	450.2		72.1	450.3	432.2	978.4	582.3	594.4	378.2	324.3		300.2
12	180.1		468 2	402 3	522.2	894.4	558.4	426.3	546.2	402.4		210.1 R. 57
13					378.2		978.3		450.2	330.3	276.3	360.3
14				552 6	228.2	1014.4	402.3	264.2	318.2	216 2	210.2	270.3 R. 49
15	30 1		378.2		210.2		618.3		258.2	384.3		
16					252.3	954.4	600.2	216.2	510.2	420.3		R. 51
17		756.3		420.3	234.3	900.4	750.2		180 1	786.4	R. 45	78.2
18		720.3			540.2	1422.5	960.2	30 2	180.1	114.3		
19			636.5		456.3	1200.3	360.2	348.3	312.1	282.2	162.2	R. 56
20	372.4	660 3		330.1	432.2	900.3	390.1	366.3	402.1	186.2		
21	228.2				432.2	630.3	486.2	408.3	330.1	360.2	R. 49 R. 50	
22	282·3	780.3			750.2		312.2		390.1	420.2		
23				678.2			138.2	822.4	420.2	582.3	R. 47	
24		558.3		732.2	390.1		84.1	978.4		564.3		
25			222.1	720.2	300.2	150.1	48.1	606.4	210.1	330.3	R. 55	120.1
26		372.2	924.5		300.2		156.2	552.3		396.3		120.1 R. 49
27			870.5		390.3		252.4	456.3	30.1	378.2		
28		150.1	474.5		636.3	150.1	426.4	402.3	54.2	330.2	60.2	48.1 R. 48
29	582.6	——	654.4	60.1	540.2	360.1	348.3	630.2		390.2		258.1 R. 54
30		——	504 4	90.1		180.1	120 1	270.2	330.1	228.2	30.1	
31		——	750.3	——		——	300.2	570.4	——		——	R 52

DAY.	JAN	FEB.	MAR.	APR	MAY.	JUNE	JULY.	AUG.	SEPT	OCT.	NOV.	DEC.
1			·56	-			..	...	...	...	.51	
2				·53	·51	.	.	...		·52		·53
3	..		·55		·50		..	.				·49
4			·59	..		..	...	·59	.	·49	...	
5	..		·53	·53	·51,·52	..	..	·53	...		...	...
6			·52			..	..	·64	..		...	...
7			·49			...	..	·55				...
8				...	...		...	·58		..		...
9					..	·58		·56	..	..	...	
10	·51	·55		..		·54	...	...		...		
11	·52			...		·52		...	...			...
12		·49	·53	...	..		.	..	...			...
13	·51		·53				..	·54	..	·49		...
14	55	·54		...		·57	..			...	...	
15		51		..			..	...		...	...	
16		47	·50	...		·57	...	...	..	...	...	...
17	·57	·55		...		...		...		·54		
18	·49	·52		..			..	..		·49		...
19			..	·62		.		..	·48			...
20		...	.	·51	·53	...	..		..	57,·60		·51
21	·57	..		...		...	..	...	...			...
22				...		...		.			...	...
23	·61			...			...	...	...		...	
24		·51		..	..	...	·68	...	...	·56		...
25					.	...	.	...	...			...
26			46	·51	...	...		..	..		...	
27	...		·61	·65	...	...	...	...		·54	...	...
28				·51		.		...		·54		...
29	...	—	...		...	...	...	...				...
30	...	—	·66	...	...	...	...	..			·49	...
31		—	..	—		—		...	—		—	...

cation to the Lords of the Committee of Council on Education to authorise the deputation of Mr. Lockyer and Captain Abney for the purpose, and to assign a grant limited to a maximum of 500*l.* to cover the necessary outlay."

We understand that the Lords of the Committee of Council on Education being fully impressed with the importance of having the proposed observations of the eclipse made, applied to the Lords Commissioners of Her Majesty's Treasury for permission to insert a sum of 400*l.* in the estimates to cover the necessary expenses. Eventually, however, the travelling expenses of the expedition were provided for by the Royal Society out of a private trust fund, and the instruments required to supplement those provided by Mr. Lockyer and Captain Abney were supplied by the Science and Art Department. As Captain Abney was not able to take his part in the expedition, his place was supplied by Dr. Schuster, F.R.S. We here acknowledge the liberality of the Peninsular and Oriental Company, and the munificent hospitality of the Khedive, who made the party his guests while they were south of Cairo. The results proved to be so numerous and novel that sufficient time has not yet elapsed for their complete discussion and publication. A statement of the preliminary results has been laid before the committee, and they cannot help feeling satisfaction that, in conjunction with the Royal Society, they have been instrumental in securing these observations.

(10.) *Lectures at South Kensington.*[55]

In the spring of last year a series of lectures on Solar Physics was delivered by the members of the Solar Physics Committee in the lecture room of the South Kensington Museum, in accordance with a suggestion made by the Lord President of the Council.

It was agreed by the Committee that each lecturer should be free to express his own opinion on any point, so that the views put forth are not to be regarded as necessarily sanctioned by the Committee as a body. The course was opened by two introductory lectures by Professor Stokes, in the second of which he took occasion to propound a new theory as to the nature of the aurora, and of the connexion between auroræ, magnetic disturbances, earth currents, and solar activity.

The next course was delivered by Professor Stewart, who gave theoretical reasons for supposing that the sun is most powerful at times of maximum sun spots, and then endea-

DAY.	JAN.	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT.	OCT.	NOV	DEC.
1				·48					·47			
2	·52											
3		·48	·68	·59			·52				·53	
4								·49				
5					48	·65						
6			·51							·56		
7				48			·54					
8			·52, ·53		·51		·55					
9	·50		·49, 50, ·54			·56				·53		
10			·63				·60				·48	
11			·45					·73	·44			·52
12					·54	·52						
13											·54	
14	·47							·53				
15									·47			
16	·56					·56						
17							·55				·46	
18			·48					·51	·44			·52
19			·47									
20	·51		·63							·54	·51	
21				·50			·52	·53				
22			·46		·66							·49
23						·60						
24		·54					·67				·54	
25								·52				
26					·54	·56						
27											·48	·54
28							·62	·54				
29		—							·46			
30		—				·51						
31		—	51	—		—	·51		—		—	

bodies, most of the collateral *experimental* work done lately has had for its object the acquisition of further knowledge bearing on this question.

For this purpose new methods of observation have been devised, and many thousand observations accumulated by means of them.

Some of these new branches of work are referred to in the following paragraphs :—

A great many experiments have been made on the distillation of most of the metals and non-metals, and some of their compounds, in vacuo, using the electric current as an explorer in order to ascertain whether any, and if so, what gases and vapours are given off at different temperatures, the permanent gases being collected and again examined both spectroscopically and chemically.

In these experiments it was noted what lines were visible at different stages of the distillation, the heat being very gradually increased.

From the data thus obtained it has been found that a connexion exists in several cases between the lines seen at different temperatures and the lines reversed in the sun.

Another series of experiments consists in volatilizing metals or their salts in a Bunsen flame, and then passing the spark from an induction coil, with or without a Leyden jar, through the flame. In this way means have been obtained of distinguishing the spectra due to high and low temperatures.

By this method of experimentation comparisons have also been made between the spectra (1) of the spark from metallic poles heated in a Bunsen flame, and (2) that of salts of the same metal volatilized in another Bunsen flame through which the spark was also passing, in this case from wires of the particular metal platinum

In this way not only have metals been compared with their salts, but also in cases where a metal exhibits two or more atomicities, compounds showing the different atomicities have been compared with one another as well as with the metal.

A series of experiments has also been made on the spectra of the arc of a Siemens's machine. It was shown that not only was there a separation of the lines of different elements at the two poles, but that in some cases one set of lines would appear at one pole while other lines of the same metal were seen only at the opposite pole. Other phenomena were also observed and recorded, such as the inverse appearance of lines, in some cases one set of lines being seen alone, in other cases other lines of the same metal appearing

DAY	JANUARY.	FEBRUARY.	MARCH	APRIL.	MAY.	JUNE.
1			K·53		K 60, ·63	K·18
2	870.3	1230 4			K·43	K·38
3			K·65, ·66	K 47, ·51		K·73
4			K·51, ·52, 58	K·49	K 48	K·44, 67
5			K 55		K·50, ·53	
6						
7	186 3	K 51, ·62	K·48, ·50			K·42, ·45
8		K·45, ·49			K·40	K·45, ·47
9	1590.4				K·47	K·59
10		K 52, ·53, ·56			K·61, ·64	K·43
11						K·41
12			K 64	K 46		
13				K 50	K 51, 53	K 48
14				K 39, 41		K·45
15				K 74		K·49
16		K·55, ·57			K 68	K·51
17	762 3			K 46, 48	K·42	K·42
18					K·44	K·42
19			K·57, ·58		K·43	
20		K 59		K·49		
21	552.3	K·48, ·50		K·40		
22	558 4			K·43	K·43, .44	
23	1080.5			K·40, 43, 49		K·47
24			K·51, ·52	K·44, ·64	K 49	
25				K·44, ·16		K·72
26	816.4			K 55, ·65	K·69	K·42
27			K·53	K·48, 54, ·56		K·65
28	1512.4	62		K 42, ·48		K·54
29	936 4	——		K 41, 48	K·46	
30		——		K·48, 52		K·43
31		——		——		——

"Discussions of the Working Hypothesis that the so-called Elements are Compound Bodies." Received 11th December 1878.

"Preliminary Note on the Substances which produce the Chromospheric Lines." Received 24th December 1878.

"Note on some Spectral Phenomena observed in the Arc produced by a Siemens' Machine." Received 3rd March 1879.

"Note on some Phenomena attending the Reversal of Lines." Received 5th March 1879.

"Discussion of Young's List of Chromospheric Lines." (Note 1.) Received 5th March 1879.

"Note on a recent communication by Messrs. Liveing and Dewar." Received 30th April 1879.

"Note on the Spectrum of Sodium." Received 28th May 1879.

"Report to the Committee on Solar Physics on the Basic Lines common to Spots and Prominences." Received 19th June 1879.

"On a New Method of Studying Metallic Vapours." Received 19th June 1879. [Distilling in Vacuo.]

"On a New Method of Spectrum Observations." Received 10th December 1879. [Passing a spark through flames.]

"Note on the Spectrum of Hydrogen." Received 16th December 1879.

"Note on the Spectrum of Carbon." Received 8th April 1880.

"Further Note on the Spectrum of Carbon." Received 11th May 1880.

"On a Sun Spot observed 31st August 1880." Received 26th October 1880.

"On the Iron Lines widened in Solar Spots." Received 13th January 1881.

"Note on the Reduction of the Observations of the Spectra of 100 Sun Spots observed at Kensington." Received 12th May 1881.

"Preliminary Report to the Solar Physics Committee on the Sun Spot Observations made at Kensington." Received 29th November 1881.

"Researches in Spectrum Analysis in connexion with the Spectrum of the Sun. No. V." Received 29th April 1878. Printed, 1881. Delay caused by preparation of the plate. (Phil. Trans.)

c.—*Bearing of this work on Solar Theory.*

The more recent work referred to in the above list taken in conjunction with the spectroscopic observations of

Day.	January.	February.	March.	April.	May.	June.
1		E··		K·43, ·45, E ··		
2			K·64, ·66	K·50, ·51, E···		
3					K·54, ·62	E···
4	E···	K·46, ·48, E···	K·68, ·69			K·46, ·52, E···
5		K·46, ·49, E···			K·66	
6		K·49, ·52			K·48, ·53	K·54, E···
7		E···			K·48, E···	K·52, ·54, E ··
8		E...		K·47, ·51		K·55, ·61
9				K·68, ·69		E···
10		K·62, ·64	K·70, ·71, E···		K·64	K·49, ·50, E···
11	E···		K·65, ·67, E···	K·43, ·49, E ··		K·47, ·49
12	E···		K·52, E···	K·46, E···	K·53, E···	
13				K·50	K·51, E···,···	K·64
14				K·54	K·51, E···	K·59
15				K·49, E···	K·48, ·49	K·71
16			K·51, ·54 E ·,··		K·49, ·52 E···,···	K·50, ·53, E···
17		K·44, ·47, ·55 E···	K·61, ·65		K·51, ·52, E··	K·58, E···
18			K·49, ·50, E···	K·48	K·48, ·49, E···	K·48
19			K·51, ·53 E··,···	K·45, ·48 E···,··	K·49, ·51, E···	
20				K·44, E···	K·48, ·49	K·50, E···
21	E···,···			K·61		K·47, ·51, E···
22				K·46, ·51, E···		
23			K·53	K·45, ·47	E···	K·61, E···
24	K·49, ·51, E···		E··		K·60, ·66, E···	K·54, ·55
25	E···			K·54, E···		
26	K·54, ·55 E ··,··			K·64, ·65	E···	
27	E···,···			E··	K·46, ·51, E···	
28	K·53, ·54 E···,···				K·45, ·50	
29	E ·,···		K·48, ·56, E ·	K·52, ·55		E··
30	K·62, ·64, E··	——	K·66, ·67	E··	K·66, ·67	K·64, E···
31		——	K·44, ·50, E ··	——		——

spectrum *quâ* any one element does not result from the vibration of the molecules of that element existing as such at any given height in the sun's atmosphere, but results from an integration of the vibrations of the germs of that element existing, perhaps distributed, from the top of the atmosphere to the bottom.

On such a view as this the absence of striking lines of the spectra of familiar elements from, and the presence of others among, the Fraunhofer lines; the very striking changes of relative intensity between the Fraunhofer lines and those seen in our laboratories belonging to the spectrum of the same substance; the fact that the lines of the same element observed at the same time either in a spot or in a prominence indicate some rapid movement and others absolute tranquility; the fact that *quâ* the same element over long reaches of the spectrum, the same line is never seen affected in both spots and prominences; the fact that the chemical constitution of the same region of the sun as determined by spots and prominences is almost absolutely different; and the fact that changes take place in the spectra of both spots and prominences from time to time, are not only easily explained but are absolutely demanded by the new hypothesis, although the old one left them as outstanding puzzles.

Professor Stewart has suggested that if solar phenomena are as the new hypothesis represents them we should expect that this alternate association at high and dissociation at low levels of solar elementary matter would greatly increase the intensity of the solar convection currents. Thus the enormously strong currents which observation reveals to us can readily be explained by adopting this hypothesis.

(2.) *Connexion between Solar and Terrestrial Phenomena.*

1.—*Sun and Magnetism.—New Theory.*

With regard to the connexion between solar activity and auroræ, magnetic disturbances, and earth currents, Professor Stokes has proposed a new theory.[55] That auroræ consist in electric discharges taking place, usually at any rate, in the higher regions of the atmosphere, is allowed on all hands; the only question is, how are these discharges occasioned, and what is the nature of the connexion between phenomena apparently so remote? Professor Stokes contends that the source of the discharge is to be sought in atmospheric electricity, which not being relieved by the thunderstorms which take place in low and moderately low latitudes accu-

DAY.	JANUARY	FEBRUARY.	MARCH	APRIL	MAY	JUNE
1	K 46, E···					K·46
2			K·47		K 66	K 51, E··
3	K 45			K·50	K 50	
4	K 53				K 44	
5		K 50, E· br.		K 50	K 44, E	E ·
6		K 48, E···	K·65	K 48, E · br		K 50
7	K·58		K·46		K 49, E ·	E ··
8	K·50, E· ·	K 48, E ·	K·50		K 44	E
9	K·46, E···		E ·		K·50	
10		K·48, E··	E ·		K 46	
11					K 52	
12	E ··	E···	K 48, E ·	K·49, E···	K·47	
13		K 49	E· ·			
14			K·41	K·44, E ·		
15	K 50, E ·				K·60	
16				K 65, E ·	K·62	E···
17		E ··		E ··br	K 47, E···	
18		K·42, E···		K 45, E	K 49, E ·	
19	K·50, E···	K·54, E···		K 54	K 48, E ·	
20	E···	K·59, E···	E···	K 46	E· ·	
21		K·54, E···	E ··	K 47, E··· br.	K 47, E···	E···
22			K·50, E ··		K 50, E···	
23	K 51 E···	K·63, E···	K·50	K·43, E···	K 55, E· ·	E · br.
24	K·40, E···	K·49, E···	K·44, E···	K·46, E···	E	K·53, E···
25				K·48, E ··	K·46	E· ·
26		K 48	E···	K·47, E··· br.	K 54	K·49, E···
27			K·53	K·48		K·50
28					K·46, E··	K 49, E···
29	K 50	———	K 42, E···		K 51, E	E···
30	E	———	K 48	K·45	K·52, E···	K·50, E ··
31		———		———	E	———

the two being that a maximum of sun spots appears to correspond to a maximum of temperature range at Toronto a couple of days later on. This, if verified, would appear to indicate (apart from the question of true periodicity) that an increase of sun spots denotes an increase of solar power.

Professor Stewart has likewise endeavoured to show that while many, at least, of the variations of weather (embracing under this term magnetical as well as meteorological changes) have a solar origin, the difference in time of occurrence of a given phase of magnetical weather at two such places as Toronto and Kew is much smaller than the corresponding difference for meteorological weather; and, accordingly, if the former can be regarded as travelling from west to east, as we know the latter to a great degree can, magnetical weather must travel much faster than meteorological, so that the magnetical weather of Great Britain, as exhibited in declination daily ranges, is possibly allied to the meteorological weather, as exhibited in temperature daily ranges, occurring six or seven days later on. In order to exhibit this likeness a detailed comparison of the two weathers at the Kew Observatory for 1871 and 1872 has been made. The result is published in the proceedings of the Royal Society.

There is no doubt that periodic inequalities, when such exist, would show themselves by fluctuations of the nature of those treated by Professor Stewart; but the question how far such fluctuations afford trustworthy evidence of the real existence of periodic inequalities, or how far they may be regarded as the residuals of merely casual fluctuations, involves some delicate considerations demanding further investigation.

As the knowledge of such periods (if well proved to exist) might lead to results of not merely theoretical but practical importance, the Committee have requested Professor Stewart to obtain in the name and for the use of the Committee from the various magnetical and meteorological observatories the items necessary to enable him to continue these researches.

(3) *Work published—*

1. *By Prof. Stewart.*

Preliminary Report to the Committee on Solar Physics on a method of Detecting the Unknown Inequalities of a Series of Observations By Balfour Stewart and Wm. Dodgson. (Pro. R.S., May 29, 1879.)

Day.	January	February.	March.	April	May.	June.
1		K 52, 52, E···	E ·	K 50, E ··	K·62, ···, E···	K·47, E· ·
2	E···			K 70	K·49, ··	
3		K· ·		K·63, ···	E···	K· 47, ···
4		K·· , E ·	E ··	E ·	K·48, ···	
5			K···, E ··	E· ·	K·49, ··, E···	K·47, ···
6			K·54, ·61, E···		K·51, ···, E ··	E···
7		E···		K·48, , E ··	K· ·, ···, E···	
8			E···		K 64, ·· , E···	K·60, E···
9			K 41, ·51, E	K·48, E···	K·71	K·54, ···, E···
10		K 44	K 45, 48	E ·		K·51, ···
11		E ··		E ··	K·46, ···	K·50
12		E· ·	K·44, ·46, E ··		K 52, ···, E···	K·67, E· ·
13	K·51, E ··	K·63		K·49	K 53, ···, E···	K·47
14				K 67, · , E ··	K·67, ·· , E···	E···
15	K 51, ·			K·45, ··, E ··	K·50, ···, E···	K·67, E···
16		E··			E···	
17		K·47, ·50, E·	K·49, ···, E···			K·70, E···
18			K·50, ·· , E··	K·66, · ·	K·47, ···, E···	K···, ···, E···
19	E···		E ···		K···, ···, E···	K·51, ···, E···
20		K·47, 63, E···	E· ·	K 62	K·59	
21	K·59	K·47, E ··		K···, E···	K·60, ···, E···	E···
22						
23			K 46, E···	K·45, ···, E···		K·69, E ··
24	K·48	E···	K 63, · ·			K·51, E···
25	K·42	K·47, E ··	K·47, ···, E··		E···	E···
26		K·64		E···	K·48, ···, E···	K·51, ···, E···
27			K 47, · · E ··, · ·	E···	K·49, ···, E···	K·62, ···
28		K·45, E···	K·54, ···		K·46, ···, E··	
29	K·46, 54, E···			E···	K·49, ···	K·49, ···
30		——		K·53, ···, E ··	K 47, ···	K·50, ···
31		——	K·49, · , E···	——		——

Day.	January.	February.	March.	April.	May.	June.
1	K 49,· ·,E···	K 54, E··	K·66, E· ·	K·64, ···	E···	K·49, ···, E···
2	K·45, ···	K 55	K·44, ···	W·35, K·45, ··		K·50, ···
3			K 51, E ··	W 43	K·50	W·25, K·48,···
4	K 61, · ,E···	K 50				
5		K 48, E· ·	K 60,···,E· ·	K·40, E··	K·50, E···	W·36, ·60 K·46, ···
6	K 47, ,E·	K 50, ··	K 48, ·		W·25	W·58, ·60
7			E ·	K·49, W·54	W·35, K·50,··· E···	K·48,···, E···
8	E ·				W·39, ·59	K·54,···, E···
9		K 54, E···	K·46, · ·			K·47,···, E···
10		K···		W·49,·58, K·61 E···	W·59, E···	K·48, ···
11			K·62,···,E· ·		E···	K·49 ···
12			K·52, E···	K 46,···, E··· W·50, 51	W·32, K·50,···	K·52,· ·, E···
13		K·50, ···		K·46,···,W·57 E···	K·66, ···	W·40
14			E· ·	K·52,···,W·57 E· ·	K·52	W·29, K·64,E···
15	K·42, ···			K·63, ···	W·35,·46, K·47	K·54,··· E···
16	W·48	K·49, E ·		W·40, ·42 K 63, ···	W·60	
17					W·27, ·42	W·49
18	W·37,·46, E···	K·55, ···	K·60	W·42, E···	K·53	
19		K·47, ·,E···		K·53	K·63, ···	E···
20	K·52, ···	K·50, ···		W·44,·45, K·63	K·47,···, E···	
21				W·37, ·63, ·65 K·67, ··, E···	K·52	
22	K 50, ···		E ··	K·52,···, E···		E···
23		K·61, ···			K·64	K·46
24	K·58, E ··	W 47		W·44,·59, E··· K·54, ···	K·49,···, E···	
25	K·49, E···	W·44, 51	K 50	W·48, ·53	W·35, K·47,···	K·48, E···
26	K·65	W 53,K·60,··· E···		K·64,···, E···	W·28, K·47,··· E···	K·47,···, E···
27	K 59	K·47, ···	K·42	K·49,···,W·63 E···		W·28
28	K 51,···,E· ·			K·50,···, E· · W·57, ·58	W·57	K·51,···, W·57 E···
29	K 61, ···	——		K·49, ···		W·30,·52, E··· K·46, ···
30	K 49,···,E ··	——		K·48, ··, E···		K·67, ···
31		——	W·40,K·67,E ·	——	K·64,···, E···	——

DAY.	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.
1	K 47		W·46, ·52	K 44, ·51, E··	E ··
2	E···		K 50		W·31, K·51, ·50 E···
3	K 63		W 48, ·49 K 53, 54	E ·	K·16, ·55, E···
4		E·· , ··	W·49, 55	W·44, K·48, ·50	K·51, ·52
5		K 54	K·45, ·47, E···	W·44, K 53, ·54 E···	K·53, E···
6	K 50, E···	K·42, ·43	W·54	W·18, K·51, ·62 E ··	K 54, E···
7	E···			K·15, 46, W·40 E ··	K·68
8		K 45, W 51	K·65, ·66	K·51, 52, E···	E···
9		E ··	W·44, ·51		K·48, ·60
10	K·46, ·48, E···	K 43, 44, E ··		W·47, K···, ···	W·33, K·62, ·64 E···
11	K 45, ·46	K·48	K 47, ·49, E ··	W 44, ·52, E··· K·46, ·48	
12	K·45, ·48, E···		K·47, ·48	K·27, ·46, ·70 W 50, ·58, E···	K·65, E···
13	K·45, ·46		W·43, E···	W·42, K·59	K·69
14	K 46, 47, E···		K·45, ·47, E···	W·31, ·37, E··· K·48, ·49	K·46, ·47, E···
15		K·53, ·54, E ··	E···	E···	
16			W·54, ·46, E··· K·62, ·64	K·29, ·45, ·46 W·47, E··	K·4 , · ·, E··· W·60, 61
17			W·48		K·50, ·62
18			W·37	K·49, ·50, E···	W·31, ·36, E··· K·49, ·58
19			W·53, K·62	W·33, K·47, ·48 E ·	K·60, ·61, E···
20		K·56, E ·	W·52, ·59, K·59 E···	W·36, K·48, ·49	K·47, ·51, E···
21		K·50	W·58	K·20, ·49, W·52 E···, ···	E···
22		K·45, ·51, E···	W·45, 53	W·37, ·52, E··· K·48, ·49	K·48, E···
23			W·44, ·59, E··· K·48, ·54	W·43, K·48, ···	K·47, ·48, E···
24	K·59	K·45, ·46, E···	K·52, E···	W·36, ·40	K·48, E···
25	K 46, E···	K·46, ·47, E ··	K·43, ·46, E· ·	K·46, ·47	K·50, ·60, E···
26	E···	K·60, ·61	E ·	K·47, ·49	K·48, ·62
27				K·49, ···, E···	K·48, ·50
28		W 42, 52		K·59	K·40, ·48, E···
29	K 46, ·47, E···	———	E···br.	W·29, ·36	E···
30		———	K 43, ··· E ··br.	K·49	K·48, ·50 E···br.
31		———	E ·	——	K·50, E···

the Indian and other sun pictures from the beginning of 1878 to the end of 1881. It is probable that the total cost of reducing and collating this back work will not exceed 1,000*l*, which might be spread over five years; and we recommend that this work be undertaken.

With respect to the future, we recommend that steps be taken to secure a reasonable prospect of daily pictures, the Astronomer Royal having undertaken to reduce such pictures as may be necessary to form a complete series.

2. *Spectroscopic Work.*—When we consider that the spectroscope has been in our possession since 1869 as an instrument for continuously observing various localized phenomena of the solar atmosphere, we cannot but express our regret that more has not been done to employ this new instrument of research; for, even yet, daily and systematized observations are almost unknown.

As there can be no question of the importance of a daily record of spectroscopic solar phenomena, we proceed next to discuss those special points to which, according to our present knowledge (and in a new subject it is more than ever important to make this qualification), our studies should be directed.

Foremost among these inquiries we would insist upon the importance of obtaining records of all phenomena visible during total eclipses of the sun. It must not be forgotten, that with regard to the structure of the sun's atmosphere, more information can be obtained during an eclipse than from a year's work on the uneclipsed sun; and with regard to the form and extent of the atmosphere generally, we already know that the changes are so great from eclipse to eclipse that inquiries may be greatly hampered in the future if we fail to obtain these records whenever opportunity occurs.

We believe that these opinions are shared by physical astronomers in other countries, and this being so, concerted action by civilized Governments may render the part to be taken by each comparatively inexpensive.

Coming to the uneclipsed sun, we find that our great needs at present are more observations of the chromospheric and prominence lines in climates where these can be easily and continuously made.

Observations of the lines widened in solar spots rank, perhaps, next in order of importance, as the facts show that the vapours which produce them are not those which give rise to the appearance of prominences. At present this work is limited to Greenwich and South Kensington, and

DAY.	JANUARY	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE
1		E·		C 82, E ··	E·	W·28, C·67, ·81 E· ·
2	K·47, ·50		W·46, ·49 E ·· br.	W 33, C 90	E	W·28, ·29, C·64
3	K·43, 45, E ·		C·84, 86	W·36, C 92	C·85	C·74, E···
4	K·47, ·48, E··	W·42	K·47, 49, E··	K 53, C·85	E··	W 34, E
5	K·47, ·48, E· ·	W 47	K 45, 46, E	K 41, 46 C 70, 74		W 33, E ·
6		W·48	K 45, ·46, E···	W·54, C 89, 92		
7	E···	K·44, ·52 W·46, 49	K 47, 48, E ·· C 81, 84	E ··	C 80, E···	W·27, 55, C·62 E···
8	K 46, ·50, E ··	K 53, 57, E ·	C·74, 76, 83 E ·	W 42	W 31, C·80, 82 E ·	W·26
9	K·45, 47	K 48, 50, E·	K 45, 46, W 52	K·46, ·47	W·39	
10		K·60	K 48, ·49	C 91	C 67, 69, 73 E ·	W·26, E···
11			K 49, ·50, C·83 E···	W 37, 38, ·51 C 93	W 42, E· ·	
12		K·47	K 45, ·46, W 54 E ·	W 35	W 36, E···	W 34
13	W·51	K 41, ·42, E···	W·45, K·47, 48 C 80, E	C·73	W·29, C·81, 85	
14	E··	K·59, 60	C·80, ·84		W 41, E· · C·73, 75, ·82	E··
15	E···		K·45, 59, E· C·77, 83		W·47, ·49	E··
16		W·44	C 74, ·77, ·83		C·74, ·81, 84	
17		W 29, K·42, 48 E··	E· ·	C 91	C 76, ·85, ·89 W·38	E···
18	E ··		C 85, 90, E	C 82, E ··	C 80, ·84, ·87	E···
19	K 45	K 43, 51, E··	E···	C 85, E ··	E···	E···
20		K 43, ·44	C 87	E· ·	E ··	E···
21		K 43, ·44, E··	C 81, ·86, E ·		C 85, E···	
22			C·90, E···		C 78, E···	W·33, ·36, E···
23	K 52, ·54	K 59	E ··	C·89, E···	E···	
24	K 49, ·50, E ··		C 72	E··	E ·	W 27, E···
25				W 53, 55, E ··	E···	W·28, 66
26		K 44, ·49, W·59	E···	E···		E···
27		C 76 ·82, E ··	C·92	C·71, E ··	W·30, C·84 E· ·	E···
28		K 51	W 48, 50, C 76 C 82, ·86, ·89	C·66	W·30, C·75 E··	E···
29		C·76		C 87, E···	W·25, C 73 E···	E···
30		——	C·74, ·82, 86	C 81, ·84, E··	E	C·71, E···
31	K·48, ·49, E ·	——		——		——

rays of the sun, and prevent these from reaching the earth It might thus happen that observations of the solar radiation made near the earth's surface might give something much less than the true increase of solar power, inasmuch as a continually increasing proportion of the solar rays would have been year after year intercepted by the atmosphere. The most obvious way of getting out of this difficulty would be to make observations at high altitudes, and we hope in addition to the records of the heat actinometer now in operation at the Alipore Observatory, near Calcutta, to obtain records from one at Lé (at a considerable elevation, about 11,000 feet, above the level of the sea). We trust also that Dr. Roscoe's chemical actinometer will be established at Lé. Furthermore, with the view of throwing light on the condition of fluctuations in the received solar radiation caused by the atmosphere, we would suggest that these actinometers should be used in conjunction with some qualitative instrument which gives an immediate graphical and visible indication of the power of the sun. A modification of an instrument devised by Mr. Winstanley would appear to be very suitable for this purpose.

Presuming that we are thus able to obtain unexceptional observations at Lé, still it is certain that there must remain an appreciable quantity of aqueous vapour in the air above.

It has been suggested by General Strachey that a travelling observer carrying with him an actinometer might ascend to a considerable height by a series of stages, making observations at each. We might thus be able to obtain a more exact estimate of the absorption of the air and moisture respectively, and thence to deduce what the true solar radiation would be if we could altogether escape the atmosphere.

We ought to mention that Professor Langley of the Allegheny Observatory is at present devoting a good deal of attention to this problem, and we are induced to hope that by the united efforts of observers in the elevated portions of both hemispheres a great deal of light may be thrown upon this important subject.

This is, perhaps, the place in which to notice another species of observation which it may soon be possible to make.

Captain Abney has discovered a method of photographing the infra red spectrum, and it is hoped that light may be thrown by this method on solar radiation. Indeed, recent observations which he undertook at an altitude of 9,000 feet tend to show that for a qualitative and partially quantitative estimate of atmospheric absorption the method promises results of high value.

Day	January	February	March	April	May	June
1	W 46, E	W 37, 38	W 38	G 5?, 65	G 51, 65	W 53, G 16, 50
2	G 47, 49 52		W 35		G 48, 52	W 30, 19 G 52, 53
3				G 64, 61		W 41
4	E			W 36	W 28, G 57	W 32, G 16, 17
5	E	W 41	W 52, 54	G 59 60	G 49	G 16, 47
6	G 55		W 41, 43 G 50, 60	G 46, 68 W 55, 57	G 43, W 49	W 41, 45
7			G 51	G 51, 53, 54 W 15	W 27, G 15, 58	
8				G 18, 19, 58	G 55,	G ,
9		W 52, E			G 18, 51	G ,
10		W 52	W 15	W 47		W 37
11		G 51, 53 55	G 62 63, 68 G 63	G 42, 12	W 20, G 52, 53	G 53
12	W 49			W 31, 33	W 25	G 41, 12
13	G 50, 52, 54 G 54, 56, E			G 62, 62		G 40, 41
14						
15					W 26	W 27, G 53, 57
16					G 13, 15	W 12
17			W 39, 40	G 47, 49		
18				G 51	W 38, G 43, 45	W 58
19					W 39	G 52, 53
20				G ,	G 12, 47	
21	G 10, E			G	G 58, 59	
22			W 33	W 42, G	W 17, G 50, '52	G 60, 62
23			W 41, G 55 61	W 42, G		G 47
24	E		W 44			W 33, 61 G 43, 49
25	E	W 37, E br	G 19, 49 W 50, 51	W 28		W 42, 49 G 51, 52
26			G 58, 58, 58		G 13, 46,	
27	G 45 48, 50 G 50, 53, 54	W 35, G 47, 51	G 59, 60	G 51, 60	W 34	W 32, G 56, 59
28	G 50	W 45, G 52	G 50, 51	G 51, 60		
29	W 38, 42	——		G 61, 71,	W 37, 38	G 41, 42
30	E	——		G 57, 58	G 44, 50	W 40, 42 G 40, 42
31	W 39, 40, 41	——		——		——

we cannot say that taking the rainfall stations as a whole there is incontestable evidence of a single rainfall period corresponding to that of sun spots. This subject is one which requires further investigation; and observation of the heights of rivers appears to be a hopeful direction in which to look for evidence bearing on this question.

In the next place, with respect to storms, the evidence appears to be favourable to an increase in the number of great atmospheric disturbances, corresponding to times of maximum sun spots, but the systematic discussion of anemometric observations has hitherto received far too little attention.

It seems to us that a study of isobaric lines may throw light upon the problems now before us. The relatively low summer barometer in the middle of continents, and high barometer at sea, and the opposite disposition of pressure which holds for the winter months, are problems which deserve further investigation.

We hope that this subject may be advanced by the discussion of a lengthened series of those excellent meteorological charts which the American Government are now publishing.

We recommend that communications should be entered into with the Meteorological Council, with the view of concerting a plan for investigating with sufficient thoroughness the nature and extent of the supposed relation between solar variability and the meteorology of the Earth.

We have no hesitation in expressing our belief that the continued, careful study of solar phenomena will prove to be of the greatest scientific value, and that there is no reason for doubting that the advance of true knowledge in this direction will, in some form or other, and sooner or later, prove to be of real practical value also, as all experience has shown that it has been in other branches of human knowledge.

Whether or not we shall ever possess the power of foreseeing the character of the seasons in this country, or to what extent they may in truth be related to those changes in the condition of the sun to which our attention is specially directed, it is of course impossible for us to say. But of the extreme importance of doing all that lies in our power to advance a sound knowledge of the laws of climate which so direcrly affect the well being of the whole human race there can be no question.

Day	January	February	March	April	May	June
1	C 67		Me 07		G 42, W 59 C 60	Me 08, G 40, ·13 W 31, C 59
2		G 49, 51, 51 Me 07	Me 10, G 59	W 42, G 46	G 53, C 64	C 89
3		Me 07	Me 09	W 41, G 42, 45	Me 10, G 50, 53	Me 07, C 58
4		G 43, 48	G 41, 42	G 41 42, W 55	Me 03, G 53 C 66	G 66
5	Me 09, G 48, 49	C 68		Me 03	G	W 64
6			G 39, 43	Me 06, C 68	G 41, 44, W 15	Me 21, C 57 W 63
7	W 49		G 41	G 41, , C 74	Mo 51, G 58, 59	Me 07, G· · , C 58
8		C 68, 72	W 44, G 50	Me 08, G 52, 53 C 71	Me 08, G 12, 52 C 67	Me 10, C 56
9		W 39	G 39, 42, 46	G 55, 56	Me 11, G 45, 51	C 66
10		G 44, 45, W 47	Me 06, G 54, 55	Me 04, C 67	G 45, 47, Mo 51	
11	Me 07	W 46, Ma	G 44, 51	Me 04, G 42, 49 C 67	G 45, 46, 49 G 50, C 63	
12	Me 05, G ,	G 45, 51, Ma C 68		Me 04, W 40 C 68	Me 03, G 56, 59 Mo 62	Me 09, G ··
13	Me 09	G 55, 56	G 61, 65	Me 05, C 65	Me 05, G 44, 46 C 65	Me 21
14		G 54, 56, 59 W 49, Ma	Me 05, G 56, C 72	G 60, 62		C 58, G
15		Me 08	G 54, 59, C 68	G 46, 55, C 67	G 56	Me 10, C 59
16		Me 10, Ma C 67	G 44, 46, Mo 53 C 67	G 54	G 50, 58, C 66	C 57, G
17		Me 11, Ma	Me 05, G 47, 48	C 66	W 38, C 66, 69	Mo 07, C 93
18	G 52, 53	Me 07, G 41, 42 C 70	Me 07, G 50, 52 C 74	G 52, 59, C 64	G ,	G 46
19	Me 10, G 53	G 52, 53, 54	G 69		Me 09, G , C 59	G 60, , W ·65
20	Me 07, C 71		G 47, 50, C 71	G 46, 47, C 67	Me 05, C·60 G	G 47, C 57
21	C 72	W 51, C 69	Me 12, Mo 42	Me 04	G 52,	Me 08, W ·65, ·65 G 44
22	G 47	Me 05 G 41, 44 G 46, 47, C 72	Me 08, G 49, 54 G 55, 56, W 30 C 82	C 64, G	Me 10, C 87	C 57, Ma ··, ···
23	G 50, 54	Me 05, C 68	Me 08, Mo 51 C 65, 69	W 33, G 60	Me 23, C 76	Me 13, C 58
24	G 45, 46, 48 C 72, Ma	G 44, 45, 47	G 41, 47, 49 Me 12, C 69	Me 22, G 39, 42 W 50, C 66	C 59	Mo 51, C 58, ·69 G ·
25	Me 06, G 50, 52 W 48, Ma	Me 10, C 68	G 41, 42	G 54, 58	Me 09, C·59	
26	Me 09, Ma C 69	Me 09, G 42		Me 03, G ,	C 57, 64, 69 Mo 09	Me 08, G·48 C 57
27	Me 11, Ma G 50		Me 09	C 65	Mo 07, C 59, ·66	W 27, C 58 G
28	Me 10, Ma	Me 05, G 53, 58	Me 11, C 67	G· ,		W 53, C 59
29	Me 07, G 44, 45	G 59	G 58, 59 60 Mo 52, C 70	W 45, C 66	C 64, G ,	Mo 09, Ma··· W 61
30		———	G 41, 43, 55 W 51		Me 20, G , · · C 65	Mo 06
31	G 45, 46	———	G 49, 50, C 68	———	Me 08, C 58	———

V.—SUMMARY OF RECOMMENDATIONS.

We have now stated, as far as our information enables us, the precise position of our knowledge of the physics of the sun at the present time, the steps that are being taken in this and other countries to increase it, and, broadly, the nature of the work that should, in our opinion, at once be proceeded with

In order to make our main recommendations perfectly definite, we proceed to bring them together as follows:—

1. That the existing information regarding sun spots be collected and published.

2. That steps be taken to obtain sun pictures from existing observatories so as to secure a daily record of the sun for the future.

3. That these pictures be reduced on a uniform system, with the co-operation of the Astronomer Royal.

4. That the system of spectroscopic observations of the sun and their reduction at present employed at South Kensington be continued.

5 That communications be opened with observatories where spectroscopic work would be likely to be prosecuted under good climatic conditions, suggesting simultaneous observations on a definite plan for a limited period, say, for three years.

6. That steps be taken, in concert with foreign Governments, to secure the observation of the phenomena of all total solar eclipses as far as possible.

7. That the experiments necessary to obtain improved instruments to record the intensity of solar radiation be continued, and that measures be taken to secure continuous observations with such instruments in suitable localities.

8. That communications be entered into with the Meteorological Council, with the view of concerting a plan for investigating with sufficient thoroughness the nature and extent of the supposed relations between solar variability and the meteorology of the earth.

APPENDIX C.

No. 70 Senate, Session of 1879.

REPORT.

Made in the name of the Commission* charged with the duty of examining the Bill, passed in the Chamber of Deputies, proposing that:—

1. A portion of the domain of Meudon be set apart for the establishment of an Observatory of Astronomical Physics;
2. Provision be made, financially, for the Observatory of Meudon

By M. A. Scheurer-Kestner,
Senator.

Gentlemen,

On the 22nd July 1874 M. Cézanne proposed, in the National Assembly, as an amendment to the estimates of the Ministry of Public Instruction, that a sum of 50,000 francs (£2,000) be provided for the creation, in the neighbourhood of Paris, of an Observatory of Astronomical Physics. In replying to M. Cézanne, the reporter to the Commission on the Budget joined in the urgent request which his colleague had addressed to the Government, he begged the latter to consider the question, recommending that M Janssen's proposal, which M Cézanne had explained to the House, should be submitted to the Academy of Sciences But, as the Government did not propose that any provision should be made, the Budget Commission did not consider it advisable to entertain the amendment, which M. Cézanne withdrew on the Minister of Public Instruction undertaking to have a Bill prepared.

The year after, on the estimates for 1876, M Cézanne brought up his amendment again, in concert with M. Paul Bert The Commission on the Budget, in a report by M Lepère, stated that, failing a proposal from Government, it would be advisable to let matters stand over until a special application was made to it for a vote. The reporter, however. observed that, as far back as the 6th August 1874, the Minister of Public Instruction, inaccordance with the wish expressed by M Bardoux in the House on the 22nd July preceding, had brought the question before the Academy of Sciences. In the Report of a Commission consisting of Messrs. Lœvy, Becquerel, Bertrand, Dumas, and Faye (reporter), it is stated "that the "Academy of Sciences entirely approves of the idea of creating in "or near Paris an Observatory specially devoted to Astronomical "Physics. Moreover, it earnestly desires to see created an establishment which appears to it to be indispensable for the progress now "required, as well as for the scientific reputation of the country."

The question was therefore under examination when the estimates for 1876 came to be discussed. But, on the 29th July 1875, M. Lepère, on behalf of the Budget Commission, informed the National Assembly that the Commission had had before them a

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* Consisting of Messrs Emmanuel Arago, *President*; A Scheurer-Kestner, *Secretary and Reporter*, Varroy, Roujat, Tamisier, Viellard-Migeon, General Duboys-Fresney, Garnier, Pomel.

Yet he, for want of material assistance, had to remain inactive, We witnessed, with perplexed wonderment, the announcement to our Academy of Sciences week after week of discovery after discovery coming from eminent men anxious to do justice to their colleague, whilst regretting his enforced silence. There was, it must be admitted, something painful for France in all this; it was really a loss of moral strength and influence.

M. Janssen had to turn his attention to other subjects, such as making delicate analyses of aqueous vapour, instructing and advising aeronauts, undertaking important expeditions on behalf of the Academy. But he was unable to set foot in that very field of discoveries which he had so brilliantly inaugurated, and he has had to leave to foreigners—the Lockyers, Zoellners, Respighis, Secchis, Tacchinis—discoveries the credit and fame of which might easily have been secured to our country.

It has been asked whether it would not be possible to place the new instruments in the old Observatory of Paris; whether such an arrangement, which of course would be much less costly, would not have the double advantage of gathering together savants who deal with branches of study which are, so to speak, parallel, and at the same time of enabling them to use all the instruments, old and new, placed at their disposal in one same Observatory.

The learned reporter of the Academy of Sciences anticipated this objection by pointing out that Physics occupies only a secondary position in our National Observatory, that the astronomers are pretty well absorbed in the parent science, and that it is only occasionally that they can take up the new subjects. "There should "certainly not be a complete separation; but, by the side of the "old Observatories of mechanical astronomy, the Academy would "gladly witness the creation of a real laboratory of celestial physics, "chemistry, and photography."

The wish expressed by the Academy of Sciences in 1873 has now become an imperative necessity, if we are not to lose the fruits of the science we have created

Impressed with this necessity, your Commission proceeded to Meudon, to ascertain for themselves what were the advantages of the site selected by Government. Under the guidance of M. Janssen they went over the domain of Meudon, and visited the Château and temporary laboratories, receiving from the Director the necessary explanations concerning the instruments, their installation, their purpose, and the way to use them. From the admirable photographs of the sun which belong to the collection, the visitors were able to judge of the striking contrast between the results obtained and the insufficient means placed at the disposal of the learned astronomer. It is the hope of the Commission that the Senate will lose no time in voting the building of the Observatory at Meudon, and thus supply a want from which our scientific reputation has been suffering for years past

The site of Meudon and its Château appear to your Commission to be most favourable for the location of an observatory; celestial observations require a clear sky, perfect immunity from tremulous motions of the ground, and an atmosphere free from the glare of gas. The site of Meudon fulfils these conditions. To the west of Paris, in a direction where west winds prevail, it is sheltered from the emanations from the city which taint and darken the atmosphere. It is near enough to secure the scientific advantages resulting from the vicinity of a great centre; it is sufficiently distant to

Observatory of Astronomical Physics which is now being built at Potsdam near Berlin, and which is intended for the same studies as those at Meudon, has had a considerable piece of ground set apart for it in the Royal Park. The same thing has been done at Vienna and Brussels.

Scientific precedent alone would therefore justify the park being appropriated to such a purpose; but this would not prevent certain portions of the domain being given up to the public In accordance with the wish expressed by M Janssen, the large terrace which is in continuance of the "Allée de Bellevue," and which used to be a place of public resort, might be restored to the residents in the neighbourhood and to the Parisians who used to frequent this beautiful spot, whence is to be had one of the finest views of the environs of Paris. As regards the Observatory, there would be no objection to this terrace being used by the public, provided that the terrace be vacated at certain hours, and that it be not lighted at night; it is therefore essential that it should form part of the grounds appropriated to the Observatory.

However, the Bill only contemplates a limited appropriation, because the question of the ultimate appropriation of the enclosed space of "la Glacière," and of that portion of the park containing the rifle ranges formerly used by the troops camping in the park, is still under consideration. The War Office has before it the question of a definitive site for these ranges, which are of paramount necessity. When this has been decided, and the ranges have been withdrawn from the park, which is not likely to take more than a year, it will then be possible to complete the appropriation and to transfer to the Observatory the whole of the private park, so as to secure that stillness and immunity from tremulous motions of the ground which are indispensable for carrying on such delicate observations as those relating to celestial physics

The "Allée des Tilleuls" which leads to the Château and the private park, being appropriated to the Observatory of Astronomical Physics, the cost of maintenance, including only lawns and walks without shrubberies or flowers, has been estimated at 15,000 francs (600*l*.) a year This sum with the 50,000 francs (2,000*l*.) included in former years make a total of 65,000 francs (2,600*l*.), which will be the usual vote, and appears in the estimates for 1880.

The complete restoration of the "Château de Meudon" has been estimated at nearly three millions of francs (120,000*l*.); the architects only ask 422,000 francs (16,880*l*.) for the partial restoration, which would, as we have seen, have the result of retaining the most interesting portions of the building, and would give a very correct idea of the style of the original structure. Of course, it is a pity not to be able to reconstruct entirely a building of such architectural merit; but, having regard to the saving effected by the new scheme of appropriation, to the important scientific requirements which it meets, and to the possibility of preserving at all events the characteristics of Mansart's work, and at the same time fulfilling the two first-named conditions of economy and utility, there should be no hesitation in adopting the proposal of the Government.

The purchase and installation of the instruments and laboratories are estimated in the Bill at 516,000 francs (20,640*l*.).

The total expenditure is 1,035,000 francs (41,400*l*.), including 97,000 francs (3,880*l*.), for repairing outhouses and enclosures.

Rainfall, and Famines. "Nature," November 25, 1880, and December 2, 1880.

39. P. Smyth. Transactions of the Royal Society of Edinburgh, Vol. XXIX., page 637; also Edinburgh Observations, Vol. XIV.

40. E. J. Stone. Proceedings of the Royal Society, Vol. XIX., page 389.

41. W. Köppen. Zeitschrift fur Meteorologie, Vol. VIII., 1873, pages 241 and 257.

42. H. F. Blanford. Letter.

43. P. Smyth. Sunshine Cycles. "Nature," January 15, 1880.

44. C. Meldrum. On a Periodicity in the Frequency of Cyclones in the Indian Ocean, South of the Equator. Report of the British Association for 1872, Part 2, page 56

45. A. Poey. Sur les Rapports entre les Taches Solaires et les Ouragons des Antilles de L'Atlantique-Nord et de L'Ocean Indien Sud. Comptes Rendus, Vol. LXXVII., 1873, page 1223.

46. H. Jeula and Dr. Hunter. Sun Spots and Famines. Nineteenth Century, November 1877.

47. C. Meldrum. On a Periodicity of Cyclones and Rainfall in Connexion with the Sun Spot Periodicity. Report of the British Association for 1873. Part 1, page 466.

48. J. N. Lockyer. The Meteorology of the Future. "Nature," December 12, 1872.

49 Same as 46.

50. G. Wex Ingenieur Zeitschrift, 1873.

51 H. Fritz. Ueber die Beziehungen der Sonnenflecken-Periode zu den Magnetischen und Meteorologischen Erscheinungen der Erde. Haarlem (Published by De Erven Loosjacs, 1878).

52. G. M. Dawson. The Fluctuations of the American Lakes and the Development of Sun Spots. "Nature," April 30, 1874.

53 "Nature," January 19, 1882.

54. Proceedings of the Literary and Philosophical Society of Manchester. March 7, 1882.

55 G. G. Stokes. "Nature," Vol XXIV., pages 593, 613. B Stewart. "Nature," Vol XXIV., pages 114, 150. J. N. Lockyer. "Nature," Vol. XXIV, pages 267, 296, 315, 365, 391. Captain Abney, R.E. "Nature," Vol. XXV., pages 162, 187, 252.

APPENDIX D.

Translation of that part of the Report of the Wilna Observatory for the Year 1871 which refers to Solar Phenomena.

In the first half of the year 1871 small scattered spots were observed in the northern hemisphere of the sun in latitude 10–22°: they had occasional off-shoots to 4°, and occasionally they appeared singly between latitudes 32° and 38°; in the month of February there were hardly any, but in March they appeared in that zone in somewhat larger numbers, widely extending between latitudes 4° and 32° in the month of June, but during all that period their total area occupied nearly one and the same extent of the solar surface.

In the month of January there was only one spot of medium size in the southern hemisphere, by the end of that month, however, there appeared, between 8° and 20° latitudes, a considerable number of spots, which succeeded each other, and which, during the months of February, March, and April, spread over an extent of the sun's surface twice and three times larger than that occupied at the same time by the northern spots In the month of May the number of the southern spots began to diminish, and reached a minimum in the middle of June.* About this time the spotted zones in both hemispheres formed a visible zig-zag as compared with their former extension, first moving to the north and then, in the middle of July, to the south After that the spots in the southern hemisphere were quite invisible until the 10th of August, and in the north the zone shifted to between latitudes 14° and 26° In the middle of August an immense spot appeared ($\frac{13}{10000}$ of the whole of the sun's surface), and a mass of small spots spread to latitude 32°, remaining within those limits to the end of the year, covering in the aggregate nearly the same space all the time. In the southern hemisphere, after an absence of spots during 20 days, a very large spot (nearly $\frac{9}{10000}$ of the whole of the sun's surface) appeared on the 12th of August, a little earlier than the immense spot in the northern hemisphere above mentioned. This rapidly diminished in size between the 18th and 23rd of August, and after this a zone of a few very small spots again described a zig-zag, moving at first towards the south. The zig-zag of the spots in the north, formed at the ame period, corresponded with this one In the month of November there was an increased activity in the southern hemisphere; the spots keeping between latitudes 8° and 22°; in the month of December there was less activity here, while in the north it increased. In the month of November the total spotted area of the south exceeded by seven times that of the north, and in December the northern spots, spreading between latitudes 2° and 26°, occupied an area four times as large as that occupied by the southern spots.

Summing up the total areas of the spots on all the *negatives* for each visible period of the sun's revolution, taking this at 27·27 days, and dividing this total by the number of views taken, we obtained approximate averages of spotted areas seen every day of the period.

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* The dates are *new style*.

APPENDIX A.

MEMORANDUM as to ONE MODE of DEALING with the INDIAN SOLAR PHOTOGRAPHS. By PROFESSOR G G. STOKES, Sec R.S

I assume the available data to be a set of photographs, each taken at a known time, and presenting one fiducial line, whether it be the shadow of an equatorially mounted wire, or the common chord of two solar images taken on the same plate after a suitable interval without disturbing the telescope in the interim

Taking the photographs in chronological order it will be convenient in the first instance to attach reference numbers to the spots, which might be written on a waste positive, or on a hand sketch. In successive photographs of what is *unquestionably* the same spot, it would be well to use the same reference number followed by a distinctive letter, A, B, C.

For anything beyond a statistical enumeration of numbers and areas the first step is to measure the position of a spot relatively to the sun's disc and the fiducial line. For this I have thought of two plans, the first the simpler and cheaper, the second the more accurate and complete.

The first is to rule with diamond on glass, or better perhaps etch on glass, a network of crosslines, the interval being, say, the 100th part of the average diameter of the photographed image. The photograph being placed with the collodion uppermost, the scale is laid on it, with the ruled lines against the collodion, and one set parallel to the fiducial line The scale might be centred on the photograph, but this would involve some trouble unless the scale were provided with slow motions in two directions, and then the photograph might be injured unless a little space were left between, in which case errors of parallax might come in. Instead of attempting more than a rough centering, it would seem best to read both limbs and the spots just as they lie, when by a simple calculation we get the abscissæ of the spots referred to the centre of the disc, and the diameter of the disc. I will suppose that the latter plan is adopted. In that case the figuring of the graduation had best go from zero on the left, instead of having the zero in the middle. Supposing the photographs about 4 inches in diameter each interval would be about the 25th of an inch, and might be divided by estimation to 10ths

We should commence with the readings taken in a direction perpendicular to the fiducial line. Using a lens we should read the first limb, the spots in succession, the second limb. A thread moving parallel to the fiducial line would be required for guiding the eye down a ruled line to the lower edge where the graduation is figured Precisely the same process would have to be gone through for the readings in the perpendicular direction.

An exceedingly simple calculation would then give the two co-ordinates of a spot measured from the centre of the image, and referred to radius 100.

It may be noticed in passing that the effect of terrestrial refraction is eliminated by referring each set of co-ordinates to the measured diameter in its own direction It is only, however, in case the

It is very probable that during a certain period of time the total areas of the northern and southern spots are always equal.

The total of the areas of all the spots on 77 photographs = 62,251, consequently, every day in the year about $\frac{1}{625}$ of the sun's surface was covered with spots. The largest spots were observed on the 17th of August. On that day immense groups were visible to the naked eye; one of them equalled 1,310 millionths and another 810 millionths of the entire surface, or about $\frac{1}{700}$ and $\frac{1}{600}$ of the visible surface; the next largest groups seen in the course of the year were in size 934 millionths, 651 millionths, and 458 millionths of the entire surface. Thus, in the year 1871 there appeared spots which were considerably larger than those observed during the maximum period of 1870.

The spots most remote from the equator were observed under 38° latitude in the north hemisphere, and under 29° in the south, the nearest to the equator were in +2° and —1°. Generally speaking, during the last three years, about the last maximum, the spots were most distant from the equator; five spots were observed near latitude 38°; three about latitude 40—43°, one at 51½° latitude, while in the Kew observations for 1864 and 1868 we found only one year 38° latitude; all the others were much nearer to the equator.

The following is a table showing the distribution of the various spots according to latitudes:—

Latitude.	1869. No. of Spots.		1869. Total Areas.		1870. No. of Spots.		1870. Total Areas.		1871. No of Spots		1871. Total Areas.	
	N	S.	N.	S.	N.	S.	N.	S.	N.	S	N.	S.
0– 2	0	0	0	0	0	0	0	0	0	1	0	60
2– 4	0	0	0	0	1	2	132	119	4	2	128	196
4– 6	0	1	0	67	3	4	407	438	4	6	217	372
6– 8	0	1	0	37	2	6	66	705	4	11	561	941
8–10	0	1	0	23	9	5	1,006	240	4	13	235	1,217
10–12	1	3	11	40	22	18	1,818	1,055	13	18	1,314	2,382
12–14	2	6	421	727	29	20	3,729	841	17	25	3,562	3,375
14–16	13	10	1,243	1,263	22	9	3,159	527	21	16	1,353	2,136
16–18	3	9	101	1,397	25	18	3,746	1,498	12	15	1,146	2,434
18–20	4	0	291	0	23	22	2,720	2,311	12	15	904	1,318
20–22	9	5	522	344	16	21	1,468	2,402	11	10	893	657
22–24	11	8	1,087	1,219	7	13	1,131	772	12	4	801	80
24–26	9	8	767	750	6	10	462	1,056	5	4	398	884
26–28	9	7	728	838	2	4	709	291	8	1	330	26
28–30	1	4	125	438	1	8	212	800	3	1	104	195
30–32	2	5	29	336	3	3	168	347	7	0	197	0
32–34	2	1	74	120	2	4	54	843	5	0	316	0
34–36	2	1	27	120	0	3	0	386	2	1	59	16
36–38	0	1	0	15	0	4	0	413	1	0	25	0
38–40	0	0	0	0	0	0	0	0	1	0	51	0
40–42	1	0	60	0	0	0	0	0	0	0	0	0
51– 5	1	0	61	0	0	0	0	0	0	0	0	0
Totals	70	71	5,547	7,934	173	174	20,987	15,044	146	143	12,594	16,289

circles, the equators of the two axes respectively. These circles are divided into degrees, or better to 20′. One pole represents the pole of the ecliptic, the other that of the sun's equator

The globe being mounted so as to turn for the ecliptic, the places of the spots referred to the celestial sphere are entered on it by means of the latitudes and longitudes found as above. When a sufficient number are entered to make it worth while, the globe is mounted so as to turn about the other axis. An arbitrary origin of time is taken, say 1879, January 1, Greenwich mean noon The dates of the photographs, reckoned from the beginning of the year in days and fractions of a day, are divided by the assumed time of the sun's rotation, and the integral rotations being omitted, the fraction of a rotation is converted into degrees. Call this angle A The spots marked on the globe for a given photograph are then all set back by the value of the angle A for that photograph, and marked on the globe in ink of a different colour.

We shall thus have depicted, not only the places of the spots on the celestial sphere, but their places on a sphere turning with the sun.

It would be desirable to lay down in the ecliptic position or rather mounting of the sphere, not only the heliocentric places of the spots, but also those of the earth in the ecliptic, and to have provided a brass limb, a little more than a quadrant, which is loose and intended merely for a ruler Perhaps a mere flexible strip of metal would be better When a spot is observed a good way from the centre of the disc, the quadrant rule should be laid down between the places of the earth and the spot, and a line, longer or shorter according as the spot was observed more or less near the edge, drawn through the place of the spot This may be afterwards useful in comparing results, since the position of the spot along the drawn line is more or less uncertain

When the globe gets too full, the entries on it can be copied out on two plane maps, one for celestial and the other for solar places, the old entries on the globe painted out, and the globe used afresh.

APPENDIX B.

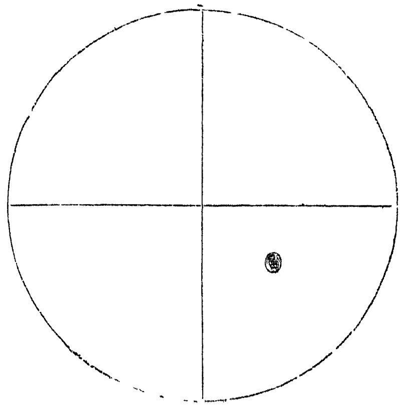
A CATALOGUE of SOLAR PICTURES and PHOTOGRAPHS, extending from the beginning of 1832 to the end of 1877. By WARREN DE LA RUE, Esq, M A, D C.L, F.R.S, and PROFESSOR BALFOUR STEWART, LL D, F.R.S

1. The first series of sun pictures having any considerable pretension to accuracy is that of Hofrath Schwabe

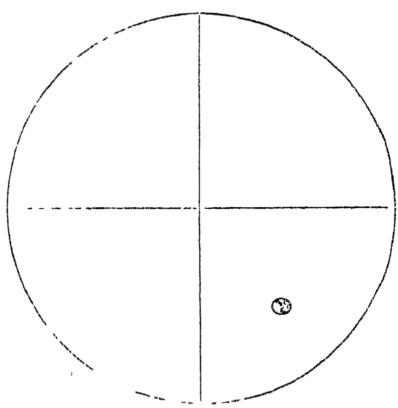
This series extends from 1825 to 1867, and the original pictures are now in the possession of the Royal Astronomical Society. Tracings taken from the whole series are in the Kew Observatory

The value of Hofrath Schwabe's drawings has been tested by Messrs. De la Rue, Stewart, and Loewy, and the results of their examination have been communicated to the Royal Society (Phil. Trans. 1870, Part II, page 389).

A cursory inspection of the drawings revealed to these observers the existence of several progressive stages in Hofrath Schwabe's



4th September —I was able to see the sun for a few minutes, and then saw that the nucleus showed more signs of internal disturbance A hasty spectroscopic examination showed that the lines were more widened than yesterday



8th September —Had a glimpse of the sun after four very cloudy days, but could not see spot Made a hasty spectroscopic examination of the sun's western limb, but could not see any prominences.

ary 25th of the same year we have three groups, of which the united area (allowance being always made for foreshortening) was 531 millionths of the visible hemisphere

5 Besides the continuous series above mentioned, Schwabe's results have been made use of to fill up a gap, extending from the end of March 1861 to the beginning of February 1862, during which interval no other regular series was taken. (In the catalogue Schwabe's pictures are recorded throughout the whole of the year 1861.)

6 The following table exhibits the list of other solar observations (besides those of Schwabe already mentioned) recorded in the present catalogue, which ends with the year 1877, this year nearly coinciding with the period of minimum sun spot frequency.

TABLE OF OTHER SOLAR OBSERVATIONS RECORDED IN THE CATALOGUE.

Name of Station.	Nature of Process.	Mark in Catalogue.
Redhill, near London (Carrington's Series)	Very accurate eye observations.	R in those cases where Carrington's observations are mixed with others
Kew Series (Dr De la Rue)	Photographic - -	K
Ely Series (Rev. W Selwyn)	Do	E
Wilna Series (Dr Smysloff)	Do.	W
Greenwich Series (the Astronomer Royal)	Do.	G
Moscow Series (Dr. P Bredichin)	Do	Mo
Cambridge, U.S. (Prof Pickering)	Do.	C
Mauritius (Dr Meldrum) -	Do.	Ma
Melbourne (Australia), Mr. Ellery.	Do.	Me

7. *Notes regarding the various Sun Pictures.*

When possible the exact time of each picture is given in Greenwich mean civil time to the hundredth of a day

Thus for instance, Carrington's picture on January 9, 1859, has the figures ·50 attached to it; this denotes that it was taken at (Greenwich) mean noon of January 9th, the civil day being reckoned from the previous midnight, so that noon denotes ·50

Sometimes, however, the exact time of the picture is not given. In this case a point and two figures are replaced by three points -- thus for instance, K · denotes such a picture taken at the Kew Observatory If there are two such pictures in a day they are indicated thus, K· ·, · · , and so on

As far as Carrington's series is concerned the absence of an exact time for a sun picture means a disk without spots.

The Ely Solar Photographs have been bequeathed by the late Canon Selwyn to the Royal Society. The exact times of these pictures have not been given by Canon Selwyn, but the Solar Physics Committee believe that they have the means of ultimately obtaining these: meanwhile, however, the days, although not the exact times, on which the Ely pictures were taken are recorded in

Greenwich 30th Oct. 1877.	Greenwich 3rd Nov 1877	Kensington 30th Aug 1879	Kensington 1st Sept 1879.	Kensington 2nd Sept 1879	Kensington 3rd Sept 1879	Metals
				4902 5 w	4902 5 d	*Fe*
				4890 7 w	4890 7 d	Fe.
				4890 0 w	4890 0 d	*Fe.*
				4888 3 w	4888 3 w	
				4888 0 w	4888 0 w	*Fe.*
					4886 4 w	*Fe*
					4885 9 w	*Fe.*
					4884 2 w	*Ti*
					4882 7 w	
				4880 9 w	4880 9 w	*Fe*
				4877·4 w w	4877 4 w	Ca. Fe
					4875 2 w	
				4871 3 w	4871 3 w	Fe.
				4870·5 w	4870 5 w	Fe
					4867 5 w w	Ti Mo.
					4863 5 w w	Th
F 4860·7	4860 7			4860·5 w	4860·5 d	H.

Sodium.

Thalen.			Spots.		Storms (Young)		Coincident Metals in Ångström's Map
Wave Lengths.	Intensities.	Coincidences.	1877 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness	
5151 8	3	.	.		3	3	
5152 5	3	Ti (2)	.	w	3	1	*Cr*
4983 3	Map	.	.	w	.		*Fe*
4982 5	4	.	.	w	.	.	
4981·9	Map		.	w	.	.	*Fe.*

Magnesium.

b_1 5183 0	1	.	w	w	50	30	
b_2 5172·0	1	Te (5)	w	w	50	35	
b_4 5166 7	1	Fe (2)	w	w	30	20	

Zinc.

5158·5	4	..	..	w w		..	
5121 0	4	Erb + Y (2)	.	..	1	1	
5074·0	4	..	.	w	..	..	Fe
5018·0	4	..	.	w	.	..	*Fe* ʼ
4971·0	4	..	.	..	.	..	
4923·8	1	.	.		.	.	
4911·2	1	..	.	.	3	2	
4878·0	5	.	..	.	.	..	

DAY.	JAN.	FEB.	MAR.	APR	MAY	JUNE	JULY	AUG	SEPT	OCT.	NOV.	DEC.
1		48.2		852.3		42.1		0.0	48.1	108.1		288.2
2	216.1	246.2				738.2		0.0		198.2		
3	450.1	228.2	648.6	240.1	456 3	840 1	0.0	24.1		78 1		462 3
4	42 3	180 2			366 3		12.1	18 2		72 1	102 2	
5	6 1		1074.7		150 2	300.1		168.1	0 0	72 1	300 1	
6			498.3	294 2		390.1	0.0	72.2	0.0		336 1	
7	0 0			294 2	1062.2	720 1	0.0	108.1	456 1			360 3
8			132.2	570 4		570 2	12.1	24 1	186.1	132 1		
9			168.2	810.4	780.1		522 2	48.1	132.1	84.2		
10	0.0	228.3					426.2	108 1	240.1	150.1		
11					720 1	228.2		78 2	240 1	108.1		
12			612 4		600 1		378.2	30 1	210 1			24.1
13		180 2	1368 5	222.2			366 2	240 1	132 1			
14		144 3			672 3		360.2		90 1	60.2		
15	36.2	540 5	1050 3	240 3	618 3		246 2	360 1	60 1	18.1	48 1	30 1
16	120.3	558.4	780 3	240 1	1728.3			300 1		0 0		0.0
17		576 5		210 1	1698.5			0·0				
18		696 4		384.1	1098 4		330 1	0 0	0.0		0 0	90 1
19		768 4		294.1				0 0	0.0			210 1
20		708.4		90.1	324.2			0.0	0 0	210 2	0 0	
21	372.4	816 5	930.4		288.2		0.0	0.0	0.0	150.1	0.0	
22		498.5		24.1			0 0	0.0	0.0	150.1	0.0	
23		1050.6		30.1	528 2		0.0	0.0	0.0	36.1	450.1	
24		846.6			312 2	516 3	18.1	0 0	0.0	90.2	276.1	198.4
25	534.3	912.5				474 3		0 0	0.0			
26				42 1	618 3		0 0	0 0	0.0	6.1	150.1	
27					672.4		0.0	0 0	0.0	0.0	240 1	258.2
28		594.4		192 3	582.3		0.0	0 0	0 0		330.1	
29			396.2	78 1	594.3	210.1	24 1		0 0			
30		——	270.2	60.1	108 1			0 0	0.0	300.1		
31		——	864.3	——		——		0 0	——	360.1	——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

Thalen			Spots.		Storms (Young)		
Wave Lengths	Intensities	Coincidences	1877. 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness	Coincident Metals in Ångstrom's Map
4919·0	3	.	.	..	..	.	
4913·2	3	.	..	.	..	..	
4911·3	3	.	..	..	..	.	
4903·0	4	Ni (3)	..	..	..	..	
4899·3	2	Ba (2)	.	.	30	6	
4884·5	1	.	.	..		.	*Fe.*
4873·0	4			.		.	
4869·0	2	.	.		.	.	
4867·5	2	Mo (4)	.	w			*Co*

MOLYBDENUM.

4979·0	5		..	.	.	.	
4867·5	1	Ti (4)		w		..	*Co.*

TUNGSTEN.

5070·5	3		.		.		
5068·0	3			w			*Fe.*
5053·0	1	.				.	
5014·4	3		.	.	.		
5007·0	3	Tl (3)	.		.	.	
4981·0	4	Ti (1)		w			
4887·5	2	.	.		.		

THORIUM.

4919·0	3	.	.	.	.		
4863·5	3			ww	..	..	*Fe.*

VANADIUM.

4881·0	3	..		..	..	.	
4874·5	3	Pd (3)	.	.	..		
4864·0	4		..	.		..	

ANTIMONY.

5177·0	3	Di+La	.	..	..	..	
5141·0	4	.	.	..	.		
5112·5	4	.	..	.	.	.	
5036·0	5	..	..	..	..	.	
4948·5	2		.	.	..	.	
4877·5	3	..	..	..	..		

DAY	JAN	FEB	MAR.	APR	MAY.	JUNE	JULY	AUG	SEPT	OCT	NOV.	DEC.
1		0.0	0 0		0.0	72.1	0.0	0 0		96.3		0 0
2		0 0	0.0		0.0	36.1	0.0	0.0	60.1	84.2		
3	72 1	18.1		102 1	0.0	0.0	0 0	54.1			120.1	
4					0.0	0.0				72 2	270.1	0.0
5	0.0	0.0	0 0		0.0	0 0		0 0	78.1		396.1	480.1
6			0.0		0.0	0.0		0.0		12.1		360 1
7			0 0	0 0	0 0	0 0	198 1	0.0		0.0	0 0	300 1
8				0.0	0.0	0.0		0 0	18.1	48.1	0.0	
9		582.1	60.1	0.0	0.0	0.0	78.1		0.0	0 0		222.2
10		378.2		0.0		0 0			216.1	0 0		
11	0 0	378 2	0.0	0.0	0 0	0 0			300.1		0.0	252.2
12	0.0	270.2	0.0	0.0	0.0	0.0	0.0	0.0			12 1	
13	30.1		0 0	0 0	42.1	0.0	0.0	0.0		0 0	468.3	
14		828.3	12.1	0.0	0.0	540.1		0.0		36.1		
15		738.3		0 0	0.0			0.0		18·1	504.3	
16		522 2		0.0	0.0	360.1		0.0	300.1			
17	51.1		0 0	0.0	0 0			0 0				
18	0.0		0.0	0.0	81.1	420.1	0.0	0.0		516.3	330.3	
19	0.0	288.2	0.0	0.0	60.1		0.0	0.0	330.1			
20			0 0	0.0			0.0	102.1		912.2	402.3	12.1
21			0.0	0.0		150.1	0 0				456.5	
22					162.2		0.0		660.1		528.5	600.1
23		180.1	0 0	0.0	120.1	300.1	321.2			480.2		576.2
24	0.0	312.1	0.0	0 0					0.0			930.3
25	0.0	36.1						0 0	0.0	570.2		
26		0 0		0.0				0 0	0.0			720.4
27		0.0		0.0		0.0		0.0				
28			0.0	0.0				0.0	0 0	474.3	21.1	
29		—	72.1	0 0	201.1	0.0		0 0	0 0	108.2		876.4
30		—	78.2	0 0		0.0	0 0	0 0	192 1			1116.4
31		—		—		—	0 0	72 1	—		—	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

APPENDIX G.

ON A METHOD OF DETECTING THE UNKNOWN INEQUALITIES OF A SERIES OF OBSERVATIONS BY PROFESSOR BALFOUR STEWART, F.R.S.*

1. Our chief reason for suspecting the existence of a connexion between the state of the solar surface (as this is revealed by spots) and the magnetism and meteorology of the Earth is derived from the fact that our observational series of sun-spots, on the one hand, and of magnetical and meteorological changes, on the other, are believed to be all subject to a common inequality, whose period (about 11 years) is virtually the same in all.

But as it is only of late years that observations of great accuracy have been made in these three branches of inquiry, it is impossible to compare together more than a few series of this long-period inequality, and hence some observers are still inclined to doubt the reality of a true connexion between the Sun and the Earth of the kind above-mentioned. We are thus led to ask ourselves whether there may not be other inequalities of shorter period in these various observations, and whether we cannot devise some means of ascertaining the exact periodical times of these as well as their other properties.

We might thus expect to decide the question regarding a connexion between these three branches, for if solar observations and those of terrestrial magnetism and meteorology all exhibit a series of inequalities that are essentially the same in each, it is impossible to call in question the reality of some connexion between them.

2. The researches of Broun, Hornstein, Buys Ballot, Baxendell, and others have indicated the probable existence of inequalities in magnetism and meteorology, with periods of comparatively short length. Messrs. De la Rue, Stewart, and Loewy have likewise observed indications of a short-period fluctuation in sun-spots; but I am not aware that any systematic attempt has yet been made to ascertain with great precision the exact period or periods of unknown inequalities either in terrestrial or in sun-spot observations.

3. In order to illustrate this method of detecting inequalities let us begin by taking a well-known case.

Suppose that we had in our possession extensive records of the temperature of the Earth's atmosphere at some one place in middle latitudes, and that, independently of astronomical knowledge, we were to make use of these for the purpose of investigating the natural inequalities of terrestrial temperature. We should begin by grouping the observations according to various periods taken, say, at small but definite time-intervals from each other. Now, if our series of observations were sufficiently extensive, and if some one of our various groupings together of this series should correspond to a real inequality, we should expect it to exhibit a well-defined and prominent fluctuation, whose departures above and below the mean should be of considerable amount. Suppose, for instance, that we have 24 points in our series, and that we group a

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* A description of this method has been given by the author in conjunction with Mr. Dodgson in a preliminary Report to this Committee, and in a second Report the method has been applied to terrestrial magnetism and meteorology. (See Pro R S, May 29, 1879, and Nov 20, 1879.) The progress of the subject since these preliminary Reports renders it desirable to recast their shape as well as to add other matter. This is done in the present communication

DAY	JAN	FEB.	MAR	APR	MAY	JUNE	JULY.	AUG	SEPT	OCT	NOV	DEC
1	864.3		2616.9	1302 6					1758 9	648.4		2112 13
2	960.1		1188.9				954.7					
3		1056 5		1068.7					1740 7			
4						468.6					396 2	
5		1866.6				654.6						
6	1152.5		678·5	1332.8	1770 7	720.7	954.8	900.5	1194.7	720 3	582.4	
7	1002.5		480.3	1296·11	1110.6		1830 9			936.4	1104.6	
8	894 6	1671 8				1611.7		732 6		630.5		
9	1074 5			2178.10	1098.6	2304.9		960.5	1128.5		1452 9	
10	1008 1		804.6	2088.9		1626 10		1350 5		1320.7		
11		882.5		1932.8	1641.7						2424.6	
12			750.9					1212.4			2304 7	
13		1050.4			1311.4			1584.5	438 2			
14	372 3				1110.4	1638 10		918.5	282.2			
15				1560.5	1446 5	1908 9		1980.6		2688 11		2724 11
16	918.5		750 1		966.6			1104.8		2700.9	2238 6	
17	672.7		291.4	1431 10		1620.8			801.5		1998 7	
18		1260 1	156.4		1074 6			552 5			2262 8	1770 11
19	665.8				1341.6		2160.8		600.4	2010 13	2148 8	
20		960.4	1101 1	1788 9	2232.6	1602 7			906.4			
21	1260.4		1620.4	1611.7	2562.6		2238.9		642.3	2478 11		2016.11
22		3216 6					1398 7	1134.5	1086.4	2952 12		
23					1011.5	1776 7	1560.6	666 6				
24	918.5			1338 6		1692.6	1632 7	576.6				
25	930 6				1671 8	1116.5	1602 7	756 7				
26	1560.7	2088.8	438.2		888.8		1356 7				978.9	
27		2250 9		1956.9	906.6			1392.8	882.5			
28			978.3				1158.4			1116 7		
29	1176.6	1836 9		1131.8		1146 6	612 3					
30		— --		1116 7	1008.6	1002 7	441.3					
31	1950.6	——	1191.7	——	1701.5	——		1986.9	——	834.4	——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

9. A glance at the sums of this table for the whole 16 years will suffice to show that 24·25 days do not correspond to the exact period of any marked inequality. The sums are small, and we conclude therefore that we have not been fortunate in our chance selection of a period to begin with, but the peculiarity of this method is, that it will enable us to ascertain the true position in the time-scale of the neighbouring prominent inequalities by means of the results of Table I. The method of doing this can easily be rendered evident Each horizontal row of Table I consists of 24 numbers, and there are 16 years, beginning with 1858. We may, therefore, call the numbers of the first row $(0)_{58}$, $(1)_{58}$, $(2)_{58}$, &c., $(23)_{58}$, those of the second row $(0)_{59}$, $(1)_{59}$, $(2)_{59}$, &c., $(23)_{59}$, and so on for each row.

In this table, therefore, each vertical column consists of similar numbers for the various years, adopting the notation now mentioned.

Suppose, however, that we displace these values as follows.—

1858 . .	$(0)_{58}$	$(1)_{58}$	$(2)_{58}$	. .	$(21)_{58}$	$(22)_{58}$	$(23)_{58}$
1859 . .	$(1)_{59}$	$(2)_{59}$	$(3)_{59}$	.	$(22)_{59}$	$(23)_{59}$	$(0)_{59}$
1860 . .	$(2)_{60}$	$(3)_{60}$	$(4)_{60}$	. .	$(23)_{60}$	$(0)_{60}$	$(1)_{60}$
. .	.	.	.	. .	.	.	.
. .	.	.	.	. .	.	.	.
1873 . .	$(15)_{73}$	$(16)_{73}$	$(17)_{73}$	. .	$(12)_{73}$	$(13)_{73}$	$(14)_{73}$

Now, if we add up the various vertical columns of this series the sums will represent an inequality somewhat larger in period than 24·25 days. For it is manifest that if we have a regular series of waves whose values we plot numerically after the manner of Table I., the consequence of adopting too small a time-scale will be to throw any salient point of the wave, such as the crest, always further and further to the right, and to correct this we should have to pull the whole series a little to the left each time Now, this is precisely what we have done in the above process, which will thus give us the representation of an inequality of a larger period than 24 25 days. It is easy to find the exact length of period which the above series represents. We pull everything to the left nearly one day, but more accurately the 24th part of 24·25 days in one year. If, therefore, 365·25 days give $\frac{24{\cdot}25}{24}$, what will 24 25 days give? We find from this proportion that the period of the inequality indicated by performing the above process is $24{\cdot}25 + \frac{(24{\cdot}25)^2}{24 \times 365{\cdot}25} = 24{\cdot}317$ days. Again, we may pull things to the left two, three, or four divisions each year, and thus obtain the representation of inequalities with periods of 24·384, 24 451, or 24·518 days

Or we may perform the opposite operation of pushing things to the right one division each year, and thus obtain the representation of an inequality, having a period of 24·183 days, while 2, 3, or 4 such divisions each year would give us periods of 24 116, 24 049, or 23·982 days.

10. It has been found necessary to push things not merely by the multiple of a whole division, right or left each year, but by the multiple of half a division.

To accomplish this we must obtain for every alternate year a series of half-way points, which is best done by converting the series

DAY.	JAN.	FEB	MAR.	APR.	MAY.	JUNE	JULY.	AUG.	SEPT	OCT.	NOV	DEC.
1	2112.9		1866 12	1962.12		558.6			750.3	120.3	1134.7	858 4
2	1812 10				858.9		1212.9	828.5	1020.3	258 4		
3	2592 10		2112.8		1158.9		1134 6		846.4	360 3	906 5	
4	3012 11	2490.4	2232.10		1350 10		300.3		1182 4			660 3
5		1638.5	1272.10			1158.6	552.4		1308 5		1008.5	426.6
6		870.4			546.6		1506 7	312 1			546.3	
7		930 3			1566.7		606 6	138 5	1368.6	558.4	594 4	
8	3252.9		828.7	732 5	1008 8		678 7	456.4	582.6	642.3	570 6	
9		1191.1			786 6	1116.7	171.7		981.6			
10		1002.1	738 5	822 5	1128.7		756 6					
11			966.5	816.6	1710.8	762.9				168 1		1308.3
12		810.1	708 8	1230.8		552.7	201 1	216 3	276.1	651 6		
13		708.1			1338.9					861 7	618.1	
14		768.1					681 5	150 5	2118.1	1062 7	78.3	
15				366.8		618.7	768.5	786 1	702 5			
16			111.6	798.10		888 7	900.6		1512 1		72.2	
17		510.2		996 10		810.7	690.8	711.6	1716 5	306.1	252.3	108·2
18		621.2	1071 5	996.8	738·6	1212 7	771 6		1212 7			78.1
19		132 2	510.5			528 7		732.5				
20		2052.1		1281.6		186.7						
21	1398.1			981 5			576.5	1278.6	156.3	756.1		96.3
22	108.2	1281 3		696.6	1188 7	831.1			111.2	270.1		162·6
23	330·2	891.5			702.7	192 1		561 5	21.1	768 4		291.6
24		1098.1	501.5	1032.1		1110.3	1776.8	621 5	102.3	420.5		561.7
25		2061·9			738.6	12 2			102.2		666.5	
26				576.6	1296.8			210.1	81.2	1518.5	381 3	1056.6
27					1212.9	522.2			72.2		171 4	1188.6
28	782 1	2628.9			1578.8	621 3	1401.9	186.3		1380.6	510.1	
29		——			1608.10	858.5	420 8		18.2		1170.1	
30	930·7	——		726.8		771.5			81 2		1068 5	951.5
31		——		——		——	1158.8		——		——	996.4

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

15. When the method is applied to Table III, we obtain the following results :—

Table IV.—Exhibiting the results of the above method applied to the numbers of Table III.

Divisions from normal.	Exact period in days.	Magnitude of inequality.
−7·5	23·5072	1310
−7·0	23·5400	1280
−6·5	23·5729	2568
−6·0	23·6057	2710
−5·5	23·6386	2128
−5·0	23·6715	1070
−4·5	23·7043	674
−4·0	23·7372	1260
−3·5	23·7700	1500
−3·0	23·8029	922
−2·5	23·8357	1394
−2·0	23·8686	1976
−1·5	23·9014	1096
−1·0	23·9343	1754
−0·5	23·9671	2464
Normal	24·0000	3364
+0·5	24·0329	2960
+1·0	24·0657	1974
+1·5	24·0986	1032
+2·0	24·1314	1548
+2·5	24·1643	2174
+3·0	24·1971	2160
+3·5	24·2300	1664
+4·0	24·2628	1278
+4·5	24·2957	1570
+5·0	24·3285	1456
+5·5	24·3614	954
+6·0	24·3943	1110

16. The results of Table IV. are exhibited graphically by means of a curve in Fig. II.*

It will at once be seen by comparing together the two curves (Figs. I and II.) that they both exhibit as nearly as possible the same positions for maximum inequalities. Thus, by selecting at random the period 24·25 days, we are by this method referred to nearly the true positions of the various maximum inequalities.

Before proceeding further it ought to be stated that the above series of observations of the Kew Declination Range has been given rather as having been that first employed for illustrating the method than as pretending to represent the best element to be discussed from a scientific point of view. Having employed this series to explain the details of the method, it has served its purpose, and we now proceed to apply the method to observations of sun-spots.

17. For this purpose, let us take daily values of total sun-spot areas and commence with Schwabe's observations which are recorded in Appendix B. These extend from 1832 to 1853 inclusive. From 1854 to 1860 inclusive we have for the same purpose Carring-

* This curve goes somewhat beyond the limits of the table

DAY	JAN	FEB	MAR	APR	MAY.	JUNE	JULY.	AUG	SEPT.	OCT	NOV.	DEC
1		1290 7	732.6	990.1	1332 4	792 3		810 1	1122 7	120 5	660.3	
2			1008 6	861.6	1002.5	1038 1	12 3	900.1	1236 7		750 3	
3	810.5	900 8		906 5	651 1	168 3	96 3		1020 1	18 1	1116 3	108 3
4		882 7	522.1	1158 6	771 5	372 2	18 3				1476 3	228 3
5	618 3	1296.7	708 1	600 5	651.7	660.2		630 3	1116 4		912 2	261 1
6			858 1	150 6	1152 7	612.2	138.3	708.3		90.2	972 2	198 3
7	966 1		1560 5		621.5	690.2	306.2		801.1	312 3		54.2
8		1122 5	1134 1	150.3		621.1		150.3	126 3	486.1	180.1	18.1
9	882 6	1116 5		516.1	630 3	618.1	288.3			618 1	900 1	156 3
10		1026.6			1101.1	900.1	366 3	810.3	1110.1		660 2	
11	642 5		918 1			288.3	678 3	270.2	1380 1		780 2	
12	732 1	516 1	240.1	171.3		690 3	516 1		696 1	618 1	570 2	
13	126.1	510.1					138 3	684.2	1224 5	330 1		516.3
14	168.5		540 2	132 2	822 3	252 3	138.3			168.1		576.3
15	156.5		114 2	0.0	558 3	564 3	528 3	198.3			864.3	618 3
16	186.7			0 0	786 5	360 3	324.1	108 2				918 1
17				0 0		534.1	198 5	360 2	1032 3	912 6	618 3	510 1
18	618 1			270 2	630 3	180.1	702 5	12 2			810 3	708.5
19			582.3	738.2	138.3	564 1	636 5	360 2				
20	132.2	12.2				330 2		234 3		132 2	771 5	
21		12 2	558.1	381.2	132 3	198.2	228.3	126 3	870.1			852 1
22		90 1	318 3			252 2		816.1	672 3	306 3	912 5	
23	702.2		138 2	534.3	624 1	198 2	186 3	792.1	918.2	360.2		510.3
24	636.2		708.6	132 1		198.2	552 3	762.3	750.2			378 3
25	816 3			852 6	360.2	300 2	60.1	618.3	810.2		702 3	246 3
26		900.1		834.6	300.2	192.3	396.1	558.1	390.2	1092 2	678.4	126.1
27	654.1		1254.5	720 5	156.3			378.3		864.2		510.4
28	534 1			654.5			150 1	618 1	180 2	504.3		180.3
29		702.6		660.5	354.3	126.3		654 5		240.1	270.2	342.3
30		— -	312.2		324.2	168.1			108.2			
31		——	1056.7	——	756.3	——	1320.1	846.6	——	180 3	——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc

1,000 that are recorded with *plus* and *minus* signs in the following table, which is in this respect identical with Tables I. and III. Before exhibiting this table it will be necessary to make two remarks. In the first place, in certain minimum years the observations which exhibit sun-spots are sometimes too unfrequent to render the year tabulated as above in rows of 24 a trustworthy representative of the inequalities we are in search of In such cases we have taken in addition, half a year on each side of the minimum year, so that we have thus the mean of two years instead of one, the central point of the series, however, being as before the middle of the minimum year.

This treatment has been applied to years 1833, 1844, 1855, and 1856.

It is also necessary to remark that it has not been deemed necessary to apply the equalisation described in Art. 8 to these sun-spot observations; but with this exception, the process already described has been exactly followed in obtaining Table V.

Table VI. has then been deduced from Table V. in the manner in which Table II. has been deduced from Table I.

The results of Table VI. are graphically represented in the diagram which accompanies this paper, Fig. III.

DAY	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT.	OCT	NOV	DEC
1			0 0	0.0	78 1	198.1		60 1	381 2			0.0
2			0 0	0 0	120.1	210.1	570.1	96.2	561 2	510.2	42.2	0 [illegible]
3	0 0		72 2	0 0	12 1	210.1	540.1	222 2	516.2	360.2	312 1	180 1
4					0.0	222.1	270 1	198.1	120.2	390 3	300 1	
5		0 0	120 2	0 0	54 1	198 1	330 1	630.2	354 2	270 2	282 2	90 1
6		[illegible] 2	198 2	18.1	132 3		132.1	552 2	348 2	258 3		
7	0 0	144 2	238.2	78 1	210.3	150.1	60.1	186.2	198 3		690 2	
8	0 0	306 2	[illegible] 2		186.1	186 1	0.0	150 1	258.1	288 3	492 2	
9	0.0	372.[illegible]			150.1	222.1	0 0	150.1	210.1			
10		[illegible] 6.2		366 2	108.3	510.2	0 0	162 1		180.1	738.3	
11		58[illegible]	180.2	912 3	108.1	324 1	0 0	342 2	228 1		762.3	390 3
12	180.1	534 2	510.2		96 2	186 1	0 0	516 2	168 1		861.3	222 2
13		360 1		522 3	90 1	300 1	0 0	510 2	210.1	192 2	756 3	
14	336.1			720.2	72 1	120.1	0 0	558 2	168 1		432.3	
15	198 2	168 2	252 2		60 1	360 1	0.0	642 2	276 1	264 3	396 3	120 1
16	138 2				276 2		0 0	528.2				120 1
17	366.2	36 1		570 2		228.2	0.0	174 2	0 0		960 5	
18	[illegible] 1		150 1	120.1	18 2	150.2	0 0	210 2	0 0	516.3	492 5	12 1
19	342 1		594.1		24 1	216 2	0 0	234.2	0.0		216.3	12 1
20		60 1	600 1	312 2	0 0	210 2	0 0		12 1	738 3		
21		120 1	72 2	96.2	0 0	336 1	0 0	54.2		624.3	180.1	
22	108 3	30 1	0 0	174.2	0.0	282.2	0.0	12.1	90.2	384 3	198.1	
23		0.0	0 0	264.2	0.0	0 0	0.0	0 0			156.2	210 1
24		0 0	0.0	180 1	0.0	0 0	0.0	0.0	18.1	450.2	270 1	
25	[illegible] 1	0 0	396 1	18.1	54 1	396.1	18.1	0.0	12.1		300 2	228 1
26	144 1	0 0	0 0	60.1	60.1	390.1	18 2	18.1	0 0		150.2	210 1
27	0.0	0.0	12.1	24.1	72.1	360.1	216 3	12.1	0 0	378 2	372.2	210 1
28	0 0	0.0	24 1	18 1	84.3	312 1	210 1	102.1	0.0	324.2		
29	0.0		0 0	156 3	156 2	312.1		270 1	78.1	270 2	12.1	222.2
30		---	0 0	144.1	312 1	120 1	192.2	192.2				
31	0.0	-	0 0	——	210.1	——		72.2	——		——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere

The number to the right of the *point* denotes the number of groups of spots present on the solar disc

shall obtain values corresponding to a change of one division every four years, or $\frac{1}{4}$th or $\frac{3}{12}$th of a division each year with sufficient accuracy

Again, inasmuch as the whole 36 years have while deducing from them Table VI. been split up for convenience into three series of 12 years each, we may take any three such series and slide the second of these so as to differ one point in phase from the first, and the third so as to differ one point from the second, and thus obtain, by summing up, an inequality corresponding to a period which differs from that of the original inequality before being so treated by $\frac{1}{12}$th of a division on either side

21 Performing this operation for the region round about 0 0 we obtain as follows —

Table VII.—Exhibiting in detail the district on either side of 0·0 (24 days).—

Period.	Magnitude.	Period	Magnitude
$-\frac{12}{12}$	22812	$+\frac{1}{12}$	27208
$-\frac{11}{12}$	25104	$+\frac{2}{12}$	30326
$-\frac{10}{12}$	26276	$+\frac{3}{12}$	25923
$-\frac{9}{12}$	25580	$+\frac{4}{12}$	23802
$-\frac{8}{12}$	25396	$+\frac{5}{12}$	20813
$-\frac{7}{12}$	23337	$+\frac{6}{12}$	20265
$-\frac{6}{12}$	23205	$+\frac{7}{12}$	17245
$-\frac{5}{12}$	22457	$+\frac{8}{12}$	16949
$-\frac{4}{12}$	19322	$+\frac{9}{12}$	17997
$-\frac{3}{12}$	14956	$+\frac{10}{12}$	20939
$-\frac{2}{12}$	15184	$+\frac{11}{12}$	20354
$-\frac{1}{12}$	26750	$+\frac{12}{12}$	24116
$\frac{0}{12}$	26390	$+\frac{13}{12}$	21364

In this district, therefore, the maximum is at $+\frac{2}{12}$, and it is this inequality which we now wish to represent after having cleared it from the influence of neighbouring inequalities Of these there are first of all three large but distant inequalities beyond the above district, the positions of which we may suppose to be given with sufficient precision by Table VI, namely, those at $-\frac{30}{12}$, $+\frac{18}{12}$, and $+\frac{36}{12}$. There are next inequalities at $-\frac{10}{12}$ and $+\frac{12}{12}$, which are perhaps sufficiently well indicated above in Table VII There is also another inequality indicated by the above table, which, after eliminating the influence of its neighbour, is found to be at $-\frac{6}{12}$. It thus appears that there are probably six inequalities, the effects of which ought to be eliminated from $+\frac{2}{12}$, and these have the positions, $-\frac{30}{12}$, $-\frac{10}{12}$, $-\frac{6}{12}$, $+\frac{12}{12}$, $+\frac{18}{12}$, $+\frac{36}{12}$

22. Let us now correct the inequality ($+\frac{2}{12}$) for the effects of these six neighbouring inequalities, taking the latter as they stand.

It will be unnecessary to describe in detail the method of applying this correction. Suffice it to say that the influence of the neighbouring inequalities is obtained and algebraically deducted

When these corrections have been applied we get the following result:—

Period.	Corrected magnitude
$+\frac{1}{12}$	29921
$+\frac{2}{12}$	32435
$+\frac{3}{12}$	30851

DAY.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY.	AUG	SEPT.	OCT.	NOV.	DEC.
1	132.1	390.1		0.0	270.1	132.2	162.1	762.4	0.0	0.0	0.0	72 1
2			0.0	0.0	270.1	6.1		726.3	0.0	0.0	0.0	288.2
3	30.1	336.1	0.0	0.0		0.0		954.3	0.0	0 0		198.2
4	36.1		24.1	0.0	330 1		240.1		0.0	0.0	18.1	216 2
5	0.0	144.2		0.0	270.1	0.0	228.1	624.3	0 0	594.1		48.2
6	0.0	36.1		0.0		0.0	258.2	528 3	0.0			
7	0.0	24.1	30 1	54.1	396 1	0.0	420.2	720.2	0.0		0.0	0.0
8	0.0			144.1	672.1	0.0	498.2	732.2	0.0	330.1	0.0	
9	0.0	12.1	24.1	54.1	90.1	0.0	780.2	660.2	0.0	210.1	0.0	72.1
10	0.0	12.1				0.0	720.2	72.1	90.1	324.3	0.0	24.1
11	414.1	0.0		66.1	0.0	0.0			78.1		132.1	0.0
12	540.1	0.0	270.1		0.0	0.0	480.1	0.0	168.1	474.3		0.0
13	360.1	6.1		36.1	0.0	0.0	360 1	0.0	450.1	450.4		0.0
14	210.1		168.1		0.0	0.0	0.0	0.0			390.1	
15	150.1		318·1	0.0	0.0	0.0	0.0	0.0	186.2		360.1	
16	210.1		240.1	48.1	0.0	0.0	0.0				414.1	1020.2
17		0.0	240.1	48.1	18.1	0.0	0.0	360.1	210.2	366.2		
18		0.0	300.1	756.3	210.1	0.0	0.0	672.1	90.2			
19		0.0	192.1	822.3	240.1	0.0	0.0		0.0			510.2
20	180.1	384.2		276.2	180.1	0.0	0.0			264.2		
21		210.2	270.1	288.2		0.0			0.0	168.1	0.0	810.2
22			396.1	480.1	24.1	0.0	30.1	360.1	0.0	150.1	0.0	522.2
23	216.1	390.2		420.1	12.1	0.0	0 0	300.1	0.0	150.1	0.0	540.1
24	0.0		12.1	516.2	288.1	18.1	0.0	264.1	0.0	150.1		330.1
25		390.2	66.2	396.2	420.1		0.0		0.0			
26	0.0		72.2	390.1	222.1		450.1	72.1	0.0	36.1	0.0	540 1
27	0.0			594.2		0.0		36.1	0.0	0 0		396.1
28	0.0			420.2		0.0	822.3	0.0	0.0	0 0		270.1
29	72.1	54.1	0.0	270.1		72.1	810.3	0.0	0 0	0.0	120.2	
30	270.1	——	0.0	270.1	198.1	390.1		0.0	0.0	0.0		
31		——	0.0	——	132.1	——	1332.4	0.0	——	0.0	——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

The position of the inequality is now therefore as nearly as possible at $+\frac{60}{12}$, or at least nearer $+\frac{60}{12}$ than $+\frac{61}{12}$.

In Table X the results of this elimination are given as before for every four years

It will be acknowledged that in Table X. there are evident traces of repetition.

Again (applying General Strachey's test), the mean difference of the individual observations of Table X from the mean of the whole series is found to be 243, while their mean difference from the respective calculated four-years' means is found to be 192. The difference is therefore reduced in the proportion of 1 to 0 78. These tests are thus in favour of the reality of the period given in Table X

The mean inequality of Table X. is graphically represented in Fig. VI. of the diagram which accompanies this paper

DAY.	JAN.	FEB.	MAR	APR.	MAY.	JUNE.	JULY	AUG.	SEPT.	OCT	NOV	DEC.
1	561.2	660.1	630.3		1020·4		1164.3	108 2	840·4		336·2	
2	480.2		978.4			372.2		132.2	840·5	342 3	534.4	588·3
3		774·2	906.5		996·4	414·2	480 1	378 3	810 4		504.3	
4		960.3	936.6		924.3	300.3	540 1	72.1	990.3	300.4		
5	270.2		1020.4	540.2		510.2	360.1	42.2	888 3	546.5		
6	408.2		882·1			420.2		114.2				1110.3
7			726.5			780.3	300.1	12.1	600 3	354·5		912.3
8		78.2			468 2	810.5			540.3	132.4		
9		54.2	360.4	360.1	576.2	1722.6	270.1		444.3	84.5		
10	246·2	21.1	444.3	798.2	612.2		390.1	534.2		78.2	336.3	
11				510.2		1458.6	456.2	132.1	1080.6	78.2		1362.5
12		120.1	210.1	402.1	672.3	1074.6		690.2	828.6			
13	36.1		288.2	786.1		1236.5		738.2			864.5	1128.4
14	180.1	342.3		780.1		738 4	180.2		1020.7	468.3		858.5
15	114.1	1170.2	402.1		486.4		24.1	762.3		720.1		900.5
16	372.1		378.2			282.4	246.2	1014.4	1338.6	486.2	690.4	
17	900.2	1278.3	300.2		948.6		348.2	852.4		420.2	420.3	642.3
18		864.3	690.3	714.3		690.4	636.3	672.4	810.7		258.3	330.3
19	810.2			738.3		390.4	852.3		1074.8		318.2	
20					390.5				654·7		480 3	
21	660.3		630.2		558.3	216.6		732.3		342.3	384.3	
22	840.3	1188.5	840.2	1500.4		210.3	426.4	750.4	654.7	324.4	354.2	
23	978.3	978.5				264.3	630.4	834.5	984 7	354.3		
24	888.4	1698.6		1170.4	492.3	306.5	456.4		900.8		318.3	
25		1500.4	1401.4	1410.4	·	306.4	330.3	1088·8	1470.8			
26		1476.6	1710.4					1266.6	1068.7			216.3
27		1470.4		660.2		90.3	438.4		924.7			
28	1296.4		528.2	378.2		102.4	420.3	366.3	1356.6		282 2	
29		——		702.4	366.3		510.3	306.4	516.4	90.1	222.2	
30		——	714.3		240.3		654.4				300.2	
31		——		——		——		678 4	——		——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

1862	+27	+65	+90	+80	+65	+27	−20	−33	−18	+5	+45	+62	+57	+33	−12	−50	−74	−79	−71	−65	−56	−52	−32	0
1863	−41	+22	+1	−3	−4	−1	+10	+8	−2	−18	−53	−81	−98	−109	−93	−71	−29	+19	+48	+85	+93	+86	+87	+64
1864	−15	−4	+14	+40	+59	+68	+59	+35	+4	−17	−24	−20	−17	−20	−24	−23	−7	[illegible]	+8	−4	−24	−36	−33	−28
1865	−83	−83	−68	−35	+3	+34	+66	+84	+88	+77	+45	+8	−22	−15	−43	−35	−12	+18	+31	+45	+27	−2	−31	−67
1866	+15	−16	−36	−59	−55	−36	−15	+16	+28	+31	+27	+4	−14	−26	−26	−14	+11	+17	+5	+9	+14	+30	+45	+45
1867	−26	−16	−11	+9	+28	+25	+23	+22	+30	+43	+45	+41	+25	+8	+9	+5	−5	−17	−36	−51	−51	−13	−31	−26
1868	+29	+9	−11	−7	+6	−12	−15	−39	−79	−91	−95	−85	−47	−12	−17	−10	−5	+4	+56	+87	+96	+102	+82	+54
1869	−57	−57	−48	−30	+9	+44	+60	+76	+77	+57	+43	+15	−11	−25	−27	−12	+7	+16	+14	−7	−22	−35	−43	−41
1870	−48	−53	−52	−47	−38	−26	−35	−29	−31	−39	−24	−17	+5	+42	+60	+70	+83	+76	+67	+45	+24	+1	−17	−31
1871	−31	+6	+2	−18	−14	−7	−12	−21	−29	−33	−43	−50	−54	−46	−16	+9	+28	+34	+33	+34	+39	+46	+35	+46
1872	−68	−57	−48	−24	+16	+57	+95	+95	+66	+12	−33	−50	−40	−5	+19	+30	+24	+18	+19	+13	+2	−26	−52	−63
1873	−66	+39	+13	−22	−25	−16	−16	−1	−9	−30	−32	−53	−67	−75	−80	−57	−30	+7	+35	+41	+66	+75	+79	+92
1874	+61	+41	+10	−23	−55	−61	−65	−74	−67	−55	−37	−10	+8	+12	+26	+30	+31	+36	+24	+17	+23	+26	+42	+60
1875	+6	+9	+21	+11	+8	+2	−9	0	−4	+4	+14	+17	+26	+17	+4	−28	−58	−57	−48	−8	+22	+25	+18	+8
1876	+37	+68	+99	+99	+93	+78	+51	+30	−13	−47	−75	−93	−86	−70	−63	−46	−27	−21	−9	+4	−4	−2	−4	+7
1877	−12	−11	−10	−2	+31	+39	+57	+62	+44	+28	−4	−33	−56	−71	−71	−67	−53	−28	+6	+29	+46	+42	+23	+11
1878	−60	−56	−35	−4	+18	+31	+38	+41	+36	+24	+17	−2	−12	−4	−5	−1	+1	0	+8	+21	+17	+5	−23	−55
1879	−35	−18	−5	+29	+38	+33	+32	+6	−4	−18	−28	−25	−22	+7	+30	+45	+53	+27	+5	−11	−31	−31	−33	−44
	−130	−57	+84	+215	+358	+361	+255	+105	−68	−190	−207	−197	−156	−156	−159	−208	−185	−60	+33	+177	+187	+96	−8	−90
																							(sum=3742)	

DAY.	JAN.	FEB	MAR.	APR.	MAY.	JUNE.	JULY.	AUG	SEPT.	OCT.	NOV.	DEC.
1				408.6	924.5	678.6				678.8	570.6	
2			768.5	516.5	1161.5	978.6	654.5	1428 7	150.5	756.9	954.6	
3		1086.8		528.5	1230.5		666.4	318.8			642.7	576 6
4	1824.10	942.7		594.6	1038.5	960.4	1044.5	738.7	558.4	708.7	720.5	1158 8
5	1620.10	1212.6			1062.5	1362.5	750.5	402.7	456 4	822 6	966 5	
6	1608 10				1392 5	786.5	936.5	570 8	420 5			1038 7
7	1974.9				1200.5	2034.10	1191.6	552.12	312.5	750.6		732 8
8	2088.9				1314.6				282.5	684.7	606·6	510.5
9		822.4		270.5	1662.5	1014.7	2310 5	678.7		588.6		798 6
10		1704.6		288.5	2394.6	1056.6	1740.8		228.5	1086.8	786.6	558.7
11		1206.6		432.7	2172.6	1266.7		534 5				1062 9
12			852.7			762.7	2232.8	702.6	348.3	1458.8	384 6	1290.10
13			678.5	636.6	816.5	768.7	2268.8	726.5	420.3			990.10
14		990.4			1122.5						480.10	906.9
15		1578.7	828.6	288.5	1536.6	552.6			366.4		702.10	
16	546.6	1296.7		444.6	990.4	546.7	690.5	954.6	702.6		924.10	
17	1704.8		894.7	486.6	906.7	1032.8		708 6	1224 7			996.7
18			621 6	420.8	900.7	666.8	1068.6			2106.8		978.9
19	1044.8					612.7	1068.6	1404.6	1908.4			
20			732.6	276.5		420.7	1668.5	1356.5	1680.6			1176.9
21		990.8	816.6	252.6	438.6		1272.6	1230 5	1698.7			1830.8
22			516.5		906.5	552.7	1224.5		2142.7		402.5	
23		384.7	450.5		876.6	720.8	1080.5			1746.8	282.4	
24			432.6	198.5	786.4		924.6		2400.8	1314.7		2142.10
25					648.3	810.6	588.5	1140.10			192.4	1974.9
26	996.9			834.6	780.4	1026.5	1032.5	1074.11	2292.7		756.6	1734·11
27	1284.11		912.6	828.6	684.6	786.5	1560.7	1068.11		318.4		1842.9
28	1398.10		948.7	756.7	594.6	936.6	1296.7	1392 8	1452.5	552.5		1908.9
29	852.10	954.6	672.6		942.6		1734.8	1398.8		648.6		2484.11
30	768.9	——	528.4			666 6	1638.8	816.7	708.8	1200.5	1422.8	1926.9
31	768.8	——	354.6	——	768.6	——	1992.9		——		——	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

32. The sun-spot inequality with period =24·011 days is represented in Fig IV., and the Toronto temperature range inequality with period =24·022 days is represented in Fig. V. of the diagram which accompanies this Appendix.

It will be noticed that there is a very considerable resemblance between the corresponding sun-spot and temperature curves, the latter lagging somewhat behind the former.

Another point worthy of remark is the small range (as compared with that of sun-spots) of the temperature inequalities. This may, perhaps, be viewed in connexion with the well-known fact that the proportional terrestrial variations which accompany or follow variations in sun-spots between years of maximum and minimum are much smaller than the proportional variations in the spots themselves.

It will likewise be noticed that in the three consecutive series of 12 yearly temperature inequalities there are considerable signs of repetition, although this is not so marked as in the corresponding sun-spot numbers.

Let us now apply General Strachey's test to these 12 yearly series precisely in the way in which we previously applied it to the sun-spot series of four years.

By its means we find that, by assuming the supposed law of variation, the mean difference is proportionally reduced from 1 to 0·56 in the case of the sun-spot inequality at $+\frac{2}{12}$, while for the corresponding temperature inequality at $+\frac{1}{12}$, it is only reduced from 1 to 0·84.

33. Let us next obtain in detail particulars of the region round about $+\frac{60}{12}$ We get the following result :—

Table XIV.—Exhibiting in detail the region on either side of $+\frac{60}{12}$.

Period.	Magnitude.	Period.	Magnitude.
$+\frac{43}{12}$	2178	$\frac{61}{12}$	6800
$+\frac{44}{12}$	2658	$\frac{62}{12}$	6682
$+\frac{45}{12}$	3546	$\frac{63}{12}$	6458
$+\frac{46}{12}$	4228	$\frac{64}{12}$	6146
$+\frac{47}{12}$	4734	$\frac{65}{12}$	6322
$+\frac{48}{12}$	4656	$\frac{66}{12}$	5940
$+\frac{49}{12}$	4240	$\frac{67}{12}$	5208
$+\frac{50}{12}$	2672	$\frac{68}{12}$	4166
$+\frac{51}{12}$	2788	$\frac{69}{12}$	3202
$+\frac{52}{12}$	2474	$\frac{70}{12}$	2736
$+\frac{53}{12}$	4250	$\frac{71}{12}$	3586
$+\frac{54}{12}$	3160	$\frac{72}{12}$	4252
$+\frac{55}{12}$	1740	$\frac{73}{12}$	4114
$+\frac{56}{12}$	2580	$\frac{74}{12}$	4714
$+\frac{57}{12}$	2880	$\frac{75}{12}$	4606
$+\frac{58}{12}$	2542	$\frac{76}{12}$	4890
$+\frac{59}{12}$	3724	$\frac{77}{12}$	5116
$+\frac{60}{12}$	5582	$\frac{78}{12}$	5068

34. We see from this table that there are evidences of well marked inequalities at $+\frac{47}{12}$, $+\frac{53}{12}$, $+\frac{61}{12}$.

DAY.	JAN	FEB.	MAR.	APR.	MAY.	JUNE.	JULY.	AUG.	SEPT.	OCT.	NOV.	DEC.
1			930.5	366.5		618.6	540 4	456.3		666.4		
2				312 5	66 1		264.4	648.3	300.5	378.5		
3		480 4	744 5		78.1		186.3	504.4	474.5	456.4		
4		474 3	600.5		330.3			420.4	648.6		930.2	
5		588.3	486.5	132.2	420 3	546.4	174.5	618.6	588.5		378.2	
6	792.7	450.3		36.1		912 6	288.6	756.6	630.2		12 1	
7						906.7		486.4	786.3	306.4	120.1	
8		240.2		51 3	588.6	1014.7	270.3		186.4	570.4		
9		702 6	1074.6	120 3		1116.9	768.6	534.3	528.5	492.6	60.1	
10		750.6	828.6		276.5	666.8	1230.4	450.4	756.4			420.3
11		984.6	1008.5		582.7	684.8	720.4	222 1	978.5	84.3		
12	846.5		816.5	726.5	372.6	606.10		372.3	192.6		78.1	480.3
13	714 5			414.4	396.5	798.6	642.6	360.4	414.5	354.4		594.4
14				540·7		666.7	714 6	480.4			162.3	504.3
15			468.5	540.6	114.5		690.5	228 4	276.4	594.4	312 3	366.3
16			486.4			804.7	912.5	234 4	432.3	822.5	171.3	
17			498.3	426 7	150.2		930.5	510.4	618.4	738 6		
18			480.4	360.6			198.4	468.4	720.6			
19			588.4	294.5	252.3	462.5	192.3	630.3				
20	726.4			600.5	366.3	516 6		444.3	1128.4			
21			630.4		708.4	624.4	132.2	720.3				
22	522 6	420.4	444.4		426.6	276.3	240.1		804.4			
23		768.5		342.3	246.4	294 4	0.0	528.4	762.4			
24			522.5		420.5	360.6	0.0		846.4		780.5	
25			672.4			462.6		354.4	1134.5		648.5	348.2
26		702.6	600.3	258.2		342.6	72 2		1086.6		786.5	
27	612 5	408.5	432.5		258.3		24.2	390.5	1362.5	240.1	582.3	372.3
28		948·6	456.5	186.3	390.5	216.3	24.1	642.5	1026.6	132.1		402.4
29	570.6	—			576.6		198.2	432.4	1158.6	30.1	534.5	144.2
30	240.3	—	246.3	336.3	510.6	408.3	372.2	180.4	564.5		678.5	150.2
31	174.4	—	372.4	—	354.5	—	546.4	252 6	—		—	

The number to the left of the *point* denotes the total spotted area for the day in millionths of the sun's visible hemisphere.

The number to the right of the *point* denotes the number of groups of spots present on the solar disc.

There are 24 years of observations common to both these tables and in what follows we shall confine ourselves to these 24 years. They are the years from 1844 to 1867 inclusive

It has been remarked in Art 32 that the range of the solar inequalities is much greater than that of the temperature inequalities; and I have found that in order to reduce both sets to nearly the same range it will be necessary to divide each term of each solar inequality by 3 655 Let us perform this division for the various 24 years' solar inequalities which we now wish to compare with the corresponding 24 years' temperature range inequalities We thus give both sets very nearly the same range.

38 We have next to decide whether the various phases of these inequalities prepared for comparison in the above manner occur in the sun before they occur in Toronto, and if so, how long before?

This may be ascertained in the following manner. If we add together algebraically as they stand a solar inequality and a corresponding Toronto inequality, say for instance, the one at 0·0, it does not follow that we shall obtain an inequality the sum of whose terms shall be equal to the sum of the 48 numbers added together without respect of sign. For the two inequalities even if precisely the same in type, may not have their corresponding phases occurring together. The signs of the numbers which we add together algebraically may therefore sometimes be different, and we shall then have to subtract the one from the other

It thus appears that if there be a want of simultaneity of phase in two such inequalities, the algebraic addition together of the two will give a result less than the sum (without reference to signs) of the 48 terms. And this falling off will be greater the greater the want of correspondence in phase.

Let us now add together algebraically the various solar inequalities (29 in all) each with the corresponding Toronto inequality, under the supposition that the phases are simultaneous in the sun and at Toronto We thus get a series of 29 inequalities representing the united result of the two. Let us then add together the various numbers of this series Let us next, on the supposition that a solar phase occurs three days before a corresponding one at Toronto, rectify this by pushing each Toronto inequality three divisions to the left before adding it to the corresponding solar inequality. We obtain by this means as before a series of 29 inequalities. Let us then add together the various numbers of this series.

39. In the following table we have exhibited the results obtained by this method of treatment.

TABLE XVI.

Algebraic sum of Solar and Toronto Inequalities:—

Sun and Toronto (together) - - -	=179285
Sun and (Toronto pushed 1 division to left) -	=186257
Sun and (Toronto pushed 2 divisions to left) -	=182402
Sun and (Toronto pushed 3 divisions to left) -	=181714
Sun and (Toronto pushed 4 divisions to left) -	=179447
Sun and (Toronto pushed 5 divisions to left) -	=178920

It thus appears that we get the greatest sum, and consequently the nearest approach to similarity of phase, when we push Toronto to the left between one and two divisions. In other words,

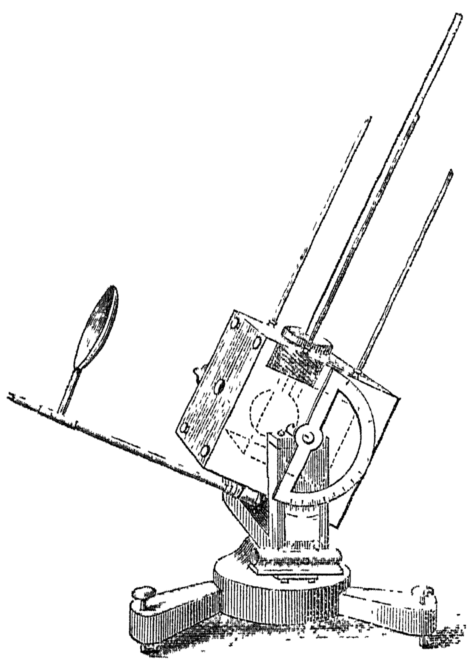
The other difficulty is of an instrumental nature Actinometers, or instruments for measuring the sun's direct heat, are made use of in the following manner:—

In the first place the instrument is sheltered from the sun, but exposed to the clear sky, say for five minutes Let the heat so lost be termed r *Secondly*, the instrument is turned to the sun for five minutes Let the heat so gained be termed R. *Thirdly*, the instrument, being now hotter than it was in the first operation, is turned once more so as to be exposed to the clear sky for five minutes while it is shielded from the sun. Let the heat so lost be termed r'.

It thus appears that r denotes the heat lost by convection and radiation united when the instrument, before being heated by the sun, is exposed for five minutes to the clear sky, while r' denotes the heat lost by these same two operations by a similar exposure after the instrument has been heated by the sun; and it is assumed that the heat lost from these two causes during the time when the instrument is being heated by the sun will be a mean between r and r', and hence that the whole effect of the sun's rays will be in reality $R + \frac{r + r'}{2}$.

Now, although this assumption may, in the average of a great number of observations represent the truth, yet in many individual cases it may be far from being true It would therefore seem to be desirable to get rid of this uncertainty by constructing an instrument in which we are sure that these causes of variability are reduced to a minimum.

This has been attempted in the instrument a sketch of which accompanies the present description.



by means of which slow motion either in altitude or in azimuth, may be given to the instrument; but these are not exhibited in the above sketch.

This description is accompanied by three memoranda, of which A and B refer to the method of adjusting the instrument and observing with it, while C embodies certain suggestions of the Solar Physics Committee regarding the best method of utilizing the observations.

(A.)

Memorandum by Professor Balfour Stewart.

The object of this instrument being to give us the relative value of the sun's direct heat from day to day and from year to year, it is necessary that all its parts susceptible of alteration should remain in a constant state, and that the observations with it should be made in a uniform manner

This will involve constancy (1) of the lens with its adjustments; (2) of the method of exposure; (3) of the thermometer and its adjustments; (4) of the method of observing with the instrument.

(1.) *The Lens with its adjustments.*

The lens is provided with several diaphragms. It should first be ascertained which of the diaphragms is most suitable to the average power of the sun at the place of observation If we take three minutes as a good time of exposure the sun should heat up the thermometer not more than three degrees or so during this time Having once selected a diaphragm the same one should invariably be used. Care should be taken to see that the glass of the lens is quite clean and not coated with the slightest film of moisture or dirt

The lens should be placed at such a distance along its rod that the focus or small image of the sun should fall not further from the bulb of the thermometer than the slit of the aperture. Generally speaking the image would naturally be formed on this slit, but in some instruments it might be desirable to have it a trifle nearer the bulb in order that the rays after they diverge again should be all well caught on the bulb of the thermometer It is of essential importance that all the rays should be so caught.

Having ascertained the best distance for the lens care should be taken that the lens is always kept at this distance and in a central position.

(2.) *The method of exposure.*

Exposure is accomplished by means of a slide, which when withdrawn uncovers a circular aperture through which the beam may fall upon the bulb of a thermometer.

Care should be taken that this slides easily as well as truly.

On the outside of the slide there is a small circular mark which, when the slide is in its place, is symmetrically above the circular aperture. This mark is decidedly larger than the sun's image When exposure is about to be made the sun's image should just be entirely within this circle at that side from which the sun carries it by his diurnal motion. Thus during the time of exposure the image will be travelling further within this circle. There can be no harm in ascertaining by experiment that the sun during the time of ex-

DAY.	JAN.	FEB.	MAR.	APR.	MAY.	JUNE.	JULY	AUG.	SEPT.	OCT	NOV.	DEC.
1			·51	·59		·50		·50	·52	·52	·51	
2		·57		·56	·57		·56	·55,·56		·51		
3											·49	
4		·51	...		·54	·55	·51		52			
5			...	·55								
6			...	·57				·59	·52		52	...
7								·52	·51			
8	·53			·51,·52				·52	·56			
9			·57		·55						48	
10		·46			·56	·55		·50	·53,·54			
11			·50					·54	·50		55	
12		·50	·52		·52				·50,·52			·53
13	·50	·57	·53,·54			·60		·50,·55				
14		·48			·54	...		·49				
15									·48		·53	
16		·52			·53		...	·57				·51
17			·48		·54	·55	...					
18		·55					·57	·61				
19	·51						·52	·47		...		
20					·50,·52		·56	·50		...		
21	·58	·50	·60	·55			·56,·57		...	...		
22	...		·51			·59	·52	...	...	...	·49	
23	...	...			·54	·52	·52				·46	
24				·46	...	·53	·50	...		·47		
25	...	...				·54,·55	·51	·51	·48			
26	...	...	·57		...	·51		53	·54			
27		...	·51			52	·61	·56	·54		·49	...
28	...	...	...		·55	·51,·56		·53	·56			...
29		——		·54		·54	·56	·53	·55		·50	
30		——			...	·54,·57	·52	·52	·56		·48	
31		——	·56	——	·52	——		·55	——	·48	——	

come so near the sun that the rays they reflect are liable to pass through the lens in such a direction as to fall on the bulb of the thermometer.

Vitiation of the observation by *visible* causes of interception of the heat rays having been thus guarded against, there still remains the possibility of casual fluctuations being produced by the invisible constituents of the atmosphere. For the detection of these, and for learning the conditions of their absence, we can only have recourse to a comparison of the results of observations made on different occasions To render such a comparison effective, memoranda should be made at the time of the observations of the condition of the atmosphere, so far as can be judged by the eye, and by readings of the ordinary meteorological instruments, and the altitude of the sun should be measured (no great accuracy being required in the measures) and recorded, or else subsequently calculated from the known time of day and year.

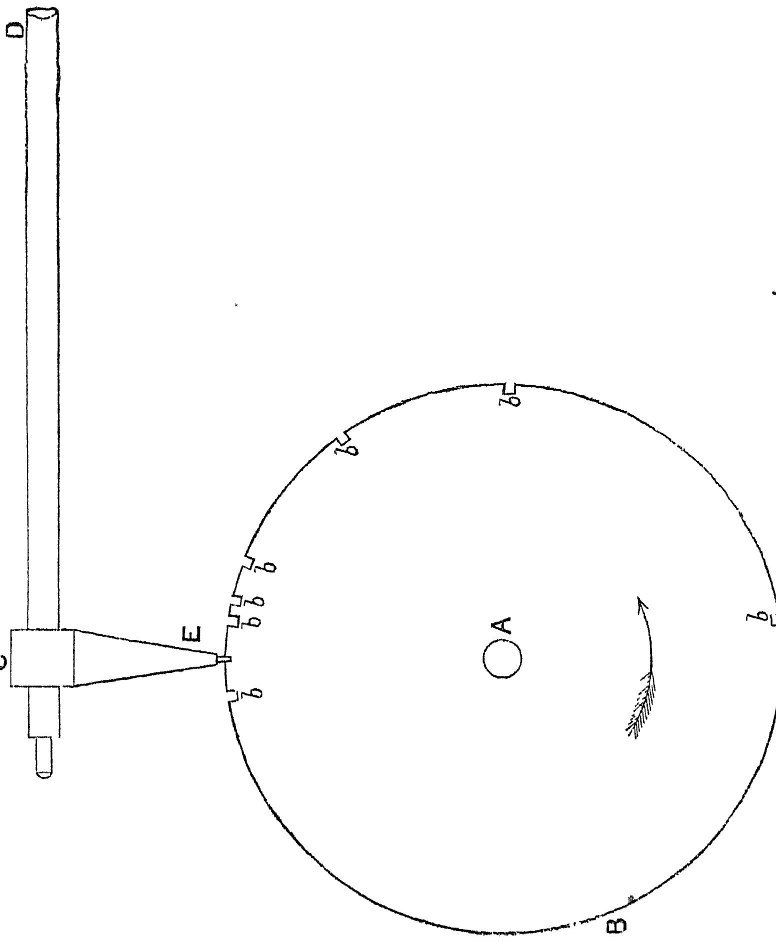
With a view to throwing light on the conditions of atmospheric fluctuations in the radiation received at the surface of the earth, the Committee would suggest that the actinometer above described should be observed in conjunction with some qualitative instrument which gives an immediate graphical and visible indication of the power of the sun. An instrument devised by Mr. Winstanley, and modified by Captain Abney, would appear to be very suitable for this purpose A complete accordance between the two instruments is not to be expected, because the thermometer in Mr Winstanley's instrument is exposed to radiation from various directions. The difference between the two instruments in this respect may be useful in throwing light on the causes of atmospheric fluctuation.

When the observer has learned how to avoid at least the grosser forms of atmospheric fluctuation, he may attack the problem of the effect of the sun's altitude on the amount of heat radiation intercepted. For this purpose specially favourable days should be chosen, and observations made at frequent intervals, from shortly after sunrise to near sunset. The condition of the atmosphere on these days should be carefully recorded. The days used for the purpose should not be confined to one season, as it is possible that the normal condition of the atmosphere at a given place, and with it the amount of absorption for a given altitude of the sun, may vary with the season All through the observations above referred to, or at least after he has learned to recognise and avoid the more serious atmospheric fluctuations, the observer must bear in mind that the instrument itself (the actinometer) is on its trial, and he must be alive to the possibility of variations in the readings, due merely to different conditions of exposure, or to other purely instrumental sources For testing the instrument itself, times should be chosen when, as far as the observer can judge, there is a freedom from casual atmospheric fluctuations, and it would be well to take a good number of consecutive observations with the screen alternately on and off.

When the observer has learned how to avoid, as far as may be, merely casual atmospheric fluctuations, and considers that the instrument has been sufficiently tested, he may commence observations taken with a view to their possibly forming part of a permanent record. For this it would be proper to get a result for each day, so so far as atmospheric conditions permit; but how many observations it would be desirable to take, whether they should be taken at stated hours, or with stated altitudes of the sun, or whether the most favourable opportunities as to atmospheric conditions should

DAY.	JAN.	FEB.	MAR.	APR	MAY.	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC
1				...		..	..	...	·58	...	·53	·49
2	..			...	...	·52	...	...	·51	.		.
3		...			.	·51	·52	·53	51		·54	
4				...	...	·51	..	...	·50		·51	.
5		...	...	...	...		...	.	·51		..	
6	..					·50	..	..	·54			
7	..			...				...	·51	...		...
8			...						...			
9		·53				·55	..	..			...	
10	...		...	·57	...	·51	..	...			..	
11					...	..		...	·52		...	...
12	...		...					..			...	..
13	...		...		...			...	·61		...	
14	..	...			..			...	·51		...	.
15	...				...	...	..	...	...		·51	..
16		...	...	·46	...	...	...	·50	...		·51	...
17				·51	...		...	·60				
18				·51	...				·56		·58	
19			...	·64	...		...		·48		·51	·50
20			...	·53	..	..			...	...		
21				·52	..	.	...	·56		...		
22			...				·53	·51				
23	...	·56	...	...			·50	·51	..		...	·54
24		...	...	...		.	·57				·53	·51
25	...			...	...	...	·47		..		·49	
26		...		...	...	...	·51	·51	...	...	·55	·47
27	...		...		...	...		·55		·46	·50	·50
28	...		...	...	·63	.	·59	..				·50
29	...	...	...		...	...	·48		...	·54	·50	...
30		——	...	...	...	..	·50	·52	...	·57	·48	
31		——	...	——		——	·51	·50	——		——	

Fig. II.



DAY.	JAN.	FEB.	MAR	APR.	MAY.	JUNE	JULY	AUG	SEPT	OCT.	NOV.	DEC
1		·51					·66	·47		·42, 43		
2							·68					
3					·53	·55				·43,·45		
4	·52		·53,·54	·58		·57	·53	·47				
5		·51			·51				53			·49
6			·61			·52	·49					
7			·65		·59	·57		·50			·48	
8		·57	·57, 58			·55	·65	·51	·56			
9	·63	·55			·54	·56						
10			·55		·50					·45		
11	·55		·51	·51			·47				·61	
12	·51		·47	·50		·51	·55		50		·47	
13	·47				·52	·51						
14	·47					·52	·51					
15			·48	·62		·52	·52	·47	·57			
16			·59	·48	·58	·53						
17	...						·52			·60		
18	·57	·57		·48	·63							
19	·53	·65	·51	·53	·55	·53		·60				·53
20			·48,·49	·62			·48					
21	·49		·51, 52	·52	·57	·57				·48	·50	
22	·58	·56	·53,·54	·52		53		·57				·47
23	·51		·54		55	·50		·70				
24	·48		54	51					·37			
25	·56			·53		·67	·49					
26	64		·50	·51	·57	·55		·57	·56			·60
27	51		·57			·62						·60
28	·51	·56	·58	·65							60	
29		—	·45		·49	·51				·37		
30		—			·53	61						
31	·49			—	·52	—			—	49	—	

	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
0	97 97	6·88	Clear	93 93	7·07	Slightly cloudy	92 92	6·92	Clear
1	86 86	6·72	Do	92 92	7·19	Clear	93 93	6·90	Do
2	96 96	6·61	Do	94 94	7·39	Sky pale	95 95	7·05	Do
3	97 97	6·95	Do	94 94	6·87	Do	96 96	6·88	Do
4	97 97	6·28	Do	95 94	7·31	Do	97 97	6·96	
5			Cloudy	94 94	7·01	Thin patches of Fk hid the sun			Cloudy
6			Do	94 94	7·51	Patches of K scattered all over the sky	93 93	6·99	
7	92 93	6·92	Scattered cumuli						
8	86 86	7·01	Sky pale	88 88	7·11	Sky pale			Do
9	81 81	7·67	Scattered cirri and cumuli all over the sky	88 88	8·15	Do	94 94	7·79	Scattered cumuli
20	97 97	7·11	Scattered cumuli	92 92	8·35	Scattered K			Cloudy
21	87 87	7·77	Do	91 91	7·58	Scattered cumuli			Do
22	86 86	6·92	Fracto cumuli	91 91	7·19	Scattered Fk almost all over the sky	92 92	6·52	Scattered cumuli
24	85 85	7·36	Clear	93 93	7·18	Clear	95 95	7·54	Clear
25	85 85	8·02	Do	94 94	7·12	Do	95 95	6·85	Do
26	85 85	6·89	Do	91 91	7·21	Sky pale and scattered Fk	93 93	6·36	Do
27	86 86	7·15	Do.	91 91	8·29	Clear	94 94	7·66	Do
28	86 86	7·28	Do	90 91	7·58	Do	90 90	7·36	Do
30	81 81	6·62	Scattered cumuli	90 90	7·39	Scattered fracto cumuli	91 91	6·95	Do
2	84 84	7·39	Clear.	89 89	7·71	Scattered cumuli.			

DAY.	JAN	FEB.	MAR.	APR.	MAY	JUNE.	JULY.	AUG	SEPT.	OCT.	NOV	DEC.
1		·50	·58	·58	·39		·58	·66	·56		·48	52
2	·52	·50	·64		·52				·45	45	46	·54
3				·63	66		·56		50	·51	51	
4				·60	·50		·53	54	52	46	·58	
5			·44		·49	36		·56	·48		55	
6		·49	·46	58	·55	55	72			·53		
7	·46			·46	48			·63	·56			
8			·62			·53	58			·40		
9		·57		·47	·64		54	55		·60	·62	50
10			·52	·60		·69		59				48
11	·46					·60	·63	·52	12		·59	
12		·54					·71		42	·51		
13		·46	·45		63		·48		·46			
14						·40		·48	·44	·64		
15		·54	·49	·54	66				·49		·52	·49
16	·48			·56						·66	52	
17	·48	·52		·48			·55	·49		·49		·60
18			·59	·51		·55	57,·71				·48	·50
19	·55			·			·53			·50	·46	·51
20		·43			·45		·56	·48		·42		·50
21				·36	·46			·52	·45			
22	·46	·58	·58	·56	45	50	·49			·15	·47	
23	50	54			·56							
24	·47	·49	·57		·58		·63		·15	·59		·58
25			·47	·58		·62	·64					
26			·45			·34		51				·50
27		·50			·50			·51			·40	
28	·58			·59				·56		·45	·58	
29		·49	·63	·53				·57		·45		
30	·59	—		·51	·38		·54	·67	·44	·49		
31		—		—		—		·53	—		—	

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1880 Nov 4				[illegible]	7 85	Thin cirri covered the sky			
" 9	77 77	7 12	Patches of Cl round the sun			Cloudy			Cloudy
" 10				84 84	8 12				
" 11	76 76	6 80	Hazy	84 84	7 01	Sun covered with thin C			
" 12	77 77	7 12	Clear	85 86	8 33	Clear	88 88	7 10	Clear
" 13	73 73	7 03	Pale sky	81 81	8 6	Do	85 [illegible]	8 01	Do
" 14	72 72	7 93	Clear	83 84	8	Do	[illegible]	8 08	Do
" 16	75 75	7 07	Sky pale	[illegible] 8[illegible]	8 28	Scattered Cl and the sky pale	86 85	8 23	Scattered cumuli
" 17	81 81	7 00		93 93	7 93	Do	88 88	7 93	Ck & K
" 18	78 78	7 01	Hazy			Cloudy			Cloudy
" 20	71 74	6 66	Sun covered with C	84 84	6 79	Sun covered with cirri			
" 22	72 72	7 36	Covered with cirri			Covered with cirri and the observations rejected			
" 23	77 77	8 26		81 81	9 15	K K C around the sun	82 82	9 07	Scattered cirri
" 24	72 72	8 16	Clear						
" 25	75 75	6 88	Scattered Ck and hazy	80 80	8 13	Scattered K & Ck sky pale	81 81	7 32	K
" 26			Sky pale and the observations rejected	80 80	7 07	Scattered K & sky pale			Cloudy
" 27				81 81	7 11	Do	96 86	7 31	Scattered cumuli
" 28	78 78	7 02	Scattered C & pale sky	81 81	8 57	Scattered C	84 84	8 05	Scattered C & pale sky

DAY.	JULY.	AUGUST.	SEPTEMBER	OCTOBER	NOVEMBER.	DECEMBER
1	1212.4	1584 7	1122.6	2190 4		1230 4 K·
2	1134 5 K···	1758.6	1152 5	1080 3		1572.5
3	1218.6		1350 5		1392 4	1512 5 K ·
4	1380 6			750 8	1860 6	2040.4 K
5	996 5	1092 5	516 6	1320 4	1410 5	2490 5 K···
6	1032.5	1200.4	690 5	930 3	612 4	
7	3180 7	1098.4	870 5	900.2	1020 5 K	
8	1902.5	510.4		924 4	K ··	
9		450 4	300 3		K ·	1350 5 K·
10		798 6		360 2	600 5	1800 6
11	2022 6	630 5		360 3	354.6 K ·	804 5 K ·
12	1452.5	1122.5	510.3			
13		930 3	828.4	486.4		2280 4
14		882 3		780 5	384 2	1350.4 K· ·
15	1050 4	618 3		828.6	K···	960.4 K·
16	1260 4	1320 3		822.6	1242 4 K	
17	1452 5	1530.4	1782.6		2082 4	
18	1140.6	2550.5	1908.7	1152.6	2040 4 K	
19	630.4	1386.4		906 6	1740 4 K	
20	870.4			1830 7		K···
21		1896.6	1260.5		2220 4	
22	1350.4	1458.6	1122 5	1440 5		
23	1620.8			1434 6	750 2 K ·	930 4
24		882 6	1572.5	1170.5	1122 5 K	1560 3
25	696 6	1380.5		1272 6	1176 4	1530.5
26	684.6	1092 6		1092 5		1620.4
27	1140 5	1086.6	1614.7	1320 6		
28			2340.6	1044.6	1620.4 K	
29	990.3	1164.4	1638 7	1050 5	1692 3	
30	1020.4				1482 4	
31	1580.5	516 5	——		——	

DAY	JANUARY.	FEBRUARY.	MARCH	APRIL.	MAY.	JUNE.
1			K·53		K 60, ·63	K·18
2	870.3	1230 4			K·43	K·38
3			K·65, ·66	K 47, ·51		K·73
4			K·51, ·52, 58	K·49	K 48	K·44, 67
5			K 55		K·50, ·53	
6						
7	186 3	K 51, ·62	K·48, ·50			K·42, ·45
8		K·45, ·49			K·49	K·45, ·47
9	1590.4				K·47	K·59
10		K 52, ·53, ·56			K·61, ·64	K·43
11						K·41
12			K 64	K 46		
13				K 50	K 51, 53	K 48
14				K 39, 41		K·45
15				K 74		K·49
16		K·55, ·57			K 68	K·51
17	762 3			K 46, 48	K·42	K·42
18					K·44	K·42
19			K·57, ·58		K·43	
20		K 59		K·49		
21	552.3	K·48, ·50		K·40		
22	558 4			K·43	K·43, .44	
23	1080.5			K·40, 43, 49		K·47
24			K·51, ·52	K·44, ·64	K 49	
25				K·44, ·46		K·72
26	816.4			K 55, ·65	K·69	K·42
27			K·53	K·48, 54, ·56		K·65
28	1512.4	62		K 42, ·48		K·54
29	936 4	———		K 41, 48	K·46	
30		———		K·48, 52		K·43
31		———		———		———

Day	July	August.	September	October.	November	December
1	K·66	K 15		K·51		
2		K·52	K·60			
3		K·51, ·52		K·45, ·64		
4		K·54	K·43			
5	K·62	K·52		K 50		
6	K·51, 54	K·52, 69	K·46			
7		K·44				
8	K·63			K·59		
9			K·49	K·45		
10		K 51	K·58	K 64		
11	K·60		K 47	K 87	K·47, ·60	
12			K·52		K 50	K 53
13	K·47				K·53	
14	K·46					
15	K·44	K·71	K 44			
16	K·44		K 52	K 44	K·49	
17	K·43			K 60	K 47	
18	K·42	K·65	K·48			
19		K·44	K 50			
20	K·49	K·46	K·40, ·64			
21	K 46	K·42		K·53		
22		K·55				
23		K·45		K 48	K·50	
24		K·47		K·43	K·52	
25	K 45, ·61	K·44, ·47	K·68			K·54
26	K·45, ·62	K·46		K·56		
27	K·43				K·50	
28	K·46	K·46				
29	K 44	K 52				
30	K·47, ·66	K·45	K 42, 44			K·54
31	K·49		——		——	

I enclose a paper containing a summary of certain spectroscopic observations made here during the past year

(Signed) C. A. Young

Letter from Dr. Buys Ballot, Utrecht

Utrecht, 22nd February 1881.

I feel very much honoured for your communications to me of your views on the methods of carrying on observations in Solar Physics, and I deplore only that I do not feel myself able to aid you in your work.

The Dutch Meteorological Institute has, to my deep regret, no personal or material assistance enough to make these observations, in which I take a very great interrst.

With great pleasure I saw that you (copy of correspondence) lay great weight on a great clearness of atmosphere on high mountains, which I think indispensable, *vide* "Changements périodiques de température dependant du Soleil et de la Lune, Utrecht 1847."

2. That you will (Preliminary Report) examine and discuss short periods; that of Mr. Balfour Stewart. As soon as I have made up the result of my own period of 27·682 days given in the above said Changements, and now confirmed by Professor Bruhns in his letter to me, I will have the honour to offer you a copy of that paper.

3. That the observations will be made with a good actinometer of Professor Balfour Stewart, which perhaps gave occasion to Mr. Violle (Rapport au Congrès météorologique de Rome, Utrecht 1878) to imagine his

I beg you to excuse that I subjected these three points to your attention in order to show you that I perused the papers you favoured me with, and amongst which plans, designs, and remarks of the highest interest are to be found

(Signed) Buys Ballot.

From Sir G. B Airy, K.C.B., M A , F R S., Astronomer-Royal.

Royal Observatory, Greenwich,
3rd March 1881.

I received your letter of December 31st in the country I have kept it in sight, and have referred to it from time to time, but business which seemed to demand my attention every moment has prevented my answering it. I fear that what I have to say now will not be very complete

The objects to which the correspondence (enclosed with your letter) applies, appear to be these, or principally these —

1. The nearly continuous photographic register of solar spots

2. The nearly continuous register of the sun's radiant heat.

1. I suppose that the uses of the solar spot register are two. (*a.*) for the changes from year to year, (*b.*) the changes from day to day.

Now on (*a.*) we have a great deal of information beginning from Wolff, and going on regularly at Greenwich, and I suppose at other places. On what they show the best evidence is that in Mr Ellis' paper on the comparison of the spot observations with magnetic observations. The exhibition (incidental to that comparison) of the numerical record of sunspots shows in short periods extreme irregularity, and in long periods an approximation to an order—

DAY	JULY.	AUGUST	SEPTEMBER.	OCTOBER.	NOVEMBER.	DECEMBER.
1	K·52	K·49, ·50	K·44	K 40, ·63, E··	K·40	E···
2	K·50, ·51				K·45	
3	K·52, ·68	K 67	K 45, E·			K 52
4	K 47, ·48, E···	K·46	E···			K·45
5	K·52	K·58, ·58, E··		K·42		E· ·, ···
6	K·40, E···, ·			K·42, ·50, E···	K·43	
7	K·49, ·50, E···	K·46, ·48, E ··	K·51, E···			E· ·
8		K·58, ·61, E· ·				
9	K·46, ·47 E···, ··				K 51, E···	
10	K·50, ·51 E ··, ···	K·48, ·60	K·42, E···			K·47, E···
11		K·48, ·49, E···	K·43, E···, ··			
12	K 50, ·51	K 49, ·51		E···	K·57, E ··, ···	E ··
13		E···		K 59	K·49	
14	K·50, E· ·	K·59		K 40, E···		K·49, E···
15	K 51, ·52	K·46, ·51				
16			K·44, E ··, ··	K·41, ·50		E···
17	K·47, ·48	K 48, E ··, ···	K 51	K·41, 60 E·· , ···		
18	K·60	K·68	K 48		E···, ··	K·45, E···
19	K·47, ·50	K 69	K·44		K·55, E···	K·53
20	E···				K·48, E···	
21			K·58		K 48	E···
22		K·56	K 52	K·63	K·43	K·51, E···, ···
23	E···		K 45, E···	K·43, ·59 E···, ··	K·42, E···	K·55
24	K·47, ·62	K 68, E···	K 65, E ·			E···
25	K 46, 49	E···	K 45, 62, E			K·42
26	K 50		K 46, ·59			E···
27						
28	K·46, 50, E· ·	K·46, E···, ···	K·55, ·61		K·48	E···
29	K 46, 51 E ·, ···	K·44, E ·	K·44, 60 E·· , ··			
30	K 46, ·47, E···		K 49, E···			K·47
31	K 47, 51, E···	K·48	– · –	K·41, 50	———	E··

apparatus measures only the luminous rays of heat, those of low refrangibility being practically all stopped by the glass lens.

Now, although the problem is essentially different from that of the measurement of lunar radiant heat, where about 18 per cent. only of the total radiation passes though glass, still, I think, we should avoid such a disposition of the apparatus as will practically measure, not the solar heat which has penetrated through our atmosphere more or less laden with moisture, as would be the case with the exposed thermopile, but that which has also penetrated through glass. Taking the piles I used for lunar radiation and the proportion, say, 1 to 80,000 for the heat radiation, and say 50 per cent. for loss at two reflecting surfaces of speculum metal, we should have to reduce the aperture from $(36)^{\prime\prime 2}$ [circular] to $\sqrt{(\frac{36}{160000})} = \frac{36}{400} = \frac{1}{11}$ of an inch to get the same deviation of the needle I only reduced the aperture to $\frac{1}{10}''$ or more, and lowered the magnet towards the needle to increase its directing force. The exposure is given by slightly moving a slide, with the hole in it placed at such a distance from the faces of the piles that the spot of sunlight may cover the same portion of the face of each pile as that covered by moonlight in the telescope. The effect of this was to substitute alternately upon each pile a spot of sky containing the sun's disc for a closely adjacent spot not containing the sun's disc, all else remaining constant. The experiment is so simple and the apparatus so cheap (10*l* for a Thomson's galvanometer, and, I suppose, a pound or two would provide the rest) that I should fancy it would be worth making *in addition* to that with Stewart's apparatus.

(Signed) ROSSE.

From Mr. H. C. Russell, the Government Astronomer, New South Wales.

Sydney Observatory, 26th March 1881.

I duly received your letter of December 31st, 1880, together with the enclosures, for which I am very much obliged. It will give me the greatest pleasure to do as much as circumstances will permit to assist in such a promising investigation as that in which you are engaged, but with the very small staff at my disposal I cannot do much. We have a daily weather map to publish, and regular returns from 189 meteorological stations, and the heavy work involved in preparing a catalogue of southern stars and the measurement of double stars. I have, however, all the necessary apparatus for photographing the sun on the American method, the focal length of the object lens being 53 feet; this I will get to work I have also a photoheliograph made for the transit of Venus, giving a picture of about 4 inches. I can use either, but from what I saw of the American transit photographs I am disposed to think that the horizontal photoheliograph gives a sharper image than the one made by Dallmeyer for the transit of Venus

I shall be very glad if you will advise me which is the better instrument for your purpose. It will be an easy matter for me to get the Dallmeyer photoheliograph altered so as to make the photograph 8 inches instead of 4 as at present. I will also obtain, as soon as I know the maker, one of Professor Balfour Stewart's actinometers for use here.

May I ask you to tell the manufacturer to send me a copy of his price list.

Day	July.	August.	September.	October.	November.	December.
1	K·64, E···	K·50, E···	K 46	K 55, E ··		K·45, E ··
2	K·51, ·55	K·68	E···			K·50, E···
3		E···	K 49, E···	K 44, E···	K 46, E···	
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6	K 63, ·64	K·53, E ··		K·46, E ··	E ··	E···
7	K·40, 50			K 58, E ·		E···
8		K·60, E···		K 48		K 58
9	K·40, ·52					K·61
10	E ··	K·48, E· ·	E ··	K·46		
11	K·50, ·52	K·47, E···, ···		K 44	E···	E ·
12	E··	K 59	E···	K·52		
13	K·63, E···	K 63, E···	E··	K ··, E··		
14	K·52, E···	E··			K·48, E ··	
15	K·51, E···	K·48	K·49, E ··, ···	K 46		
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17	E···		K·46			
18		K·52, E···	E···	K 48	K·50	
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25	K·61, E··	K·48, E···			K·51, E···, ···	
26	K·50, ·59, E ··	K 55, E· ·	E···		E ··	
27	K·64, ·65	E·	K·40, E···		E ··	
28	E···		K·60, E···	K 49, E···		E ··
29	K·51, E···	E· ·	K·45, E···		K·53, E· ·	
30		K 52, E	K·62		·	
31			——	K·55, E ·	——	

War Department,
Office of the Chief Signal Officer,
Washington City,
November 9th, 1881.

SIR,

YOUR valued communication of December 31st, 1880, as you have already learned, through some mishap failed to reach me, but a second copy, together with the enclosures, has been kindly forwarded and received.

You will be pleased to learn that the subject of Solar Physics has already been considered by me as one of fundamental importance in Meteorology, and that I had already in April last taken steps toward the investigation of the total amount of solar heat received by the earth; and to this end Professor S. P. Langley has during the last summer occupied the summit of Mount Whitney, Cal., where, at an altitude of over 14,000 feet, many important observations have been made, a full account of which you will, of course, receive when published by this Office.

The general subject of solar and terrestrial radiation is also being provided for by the introduction of Viollé's Conjugate Bulbs and Marie Davy's Conjugate Thermometers at a number of Signal Service Stations. Corresponding observations of the standard actinometer at this Office will, of course, be made. Observations of the solar spots are made for this Office by Professor D. P. Todd, now of Amherst, Mass. I shall be glad to have these conducted on a system uniform with those of European observers, and will be obliged to you for any suggestion you may make. If practicable I may even entertain the proposition of maintaining a series of daily photographs of the sun's surface, unless indeed some other of your American correspondents may have already undertaken this work.

With assurance of my high regard,

I am, &c.,

J. F. B. HAZEN,

Brig. and Bvt. Maj. Genl.,

Chief Signal Officer, U.S.A.

Professor G. G. Stokes,
Science and Art Department,
South Kensington, London, England.

SECOND REPORT

BY THE

COMMITTEE ON SOLAR PHYSICS

APPOINTED BY THE

LORDS OF THE COMMITTEE OF COUNCIL ON EDUCATION.

Presented to both Houses of Parliament by Command of Her Majesty.

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1889.

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E··	K 44, E···				
K·63	E··	E···	K·60	K 47	K 47, E· br.
K 62	K·67, E ·			K 50, E·	E ··
K·47	·	K·60		K·40	·
				E ·	
	E···		E ··		
		K·51, E···	K·51, E··· br.		
	E···	K·45, E···		K 45	
	E···		K 43, E···	K·48, E···	
	E···	K·60	E··· br.	K·53, E···	
		K·53, E···	K 48	K 50, E ··	K·50
K·47	K·44, E ··	E···		K 45, E ·	
	K·45, E· ·	———	K 43, E··	———	

(2.) A Dallmeyer photoheliograph with 4 in. photographic object glass belonging to the Greenwich Observatory.

Mr. Lockyer was stationed at Grenada, but he was unfortunately prevented from making observations by the unfavourable state of the weather.

A communication from Professor Tacchini relative to the observations that it was desirable to make will be found in Appendix II.

Eclipse of 1887.

No special measures were deemed requisite in connexion with this eclipse, it having been understood that all needful steps would be taken by the Russian astronomers

3. Solar Photographs and Tabulation of their Results.

A memorandum was presented by Professor Balfour Stewart in March 1883 on the work necessary to complete the record of sun pictures up to the end of the year 1887. The Committee were of opinion that this is a very valuable and necessary investigation for the advancement of our knowledge of Solar Physics, and they requested the Astronomer Royal and Professor Balfour Stewart to consider and report on the above memorandum, and generally on the best method of tabulating sun-spot data (*see* Appendix No III.). The suggestions made in this report were adopted by the Committee.

A letter from Professor Stewart relative to the proposed method of recording daily information regarding sun spots, together with the observations of the Astronomer Royal and of Professor Stokes thereon having been considered, the Committee resolved that the rejection of spots near the limb was not desirable, and that it was expedient that the daily sums of projected areas should be given as well as those corrected for foreshortening.

In view of the presumed superiority of the 8-inch photographs of the sun over the 4-inch, it was resolved that the Indian Government be requested to revert to the 8-inch photographs, 12-inch photographs in addition being taken when the atmosphere is particularly clear, and that steps be taken to induce the Directors of Observatories possessing photoheliographs on the Greenwich pattern to have them adapted to take 8-inch pictures.

In reply to an inquiry by Colonel Haig, R.E., relative to silver and cyanotype prints of Indian photographs, and a

5. To facilitate work on spot spectra and discussions other than those of area and position of spots, the proofs of the "Greenwich Photographic Results" as soon as received to be sent to South Kensington, and also when required the Greenwich numbering of the spots observed at South Kensington.

6. Also, when required, negatives to be exchanged between South Kensington and Greenwich so as to form a second series in the Science Museum as a safeguard against loss by fire or otherwise.

Mr. Lockyer was requested to prepare a specimen of the plate and accompanying data which he proposed to publish embodying the various information collected at different observatories; also to obtain an estimate of the cost of preparation and of reproduction.

Mr. Lockyer reported that it had become necessary to readjust the slit of the Photoheliograph and the cross wires, and requested authority to ask Mr. Dallmeyer to do this; also to provide a tertiary magnifier, at an estimated cost of 15*l*., to test the possibility of obtaining large photographs of the sun spots in this manner.

4. Solar Spectroscopic Observations.

In February 1886 Mr. Lockyer reported that 700 observations of spot spectra had been made and 200 finally reduced. The Committee directed that the observations should be printed and circulated together with the necessary maps.

Mr. Perry was invited to prepare his observations on the spectra of sun spots between D and B in the same form as Mr. Lockyer's observations in order that they may be published together.

Mr. Lockyer reported that the spectroscope which had been lent by the Indian Government had been recalled, and that the commencement of a series of observations taken under new conditions was thereby necessitated. A spectroscope would be required.

A communication was directed to be made to the India Office suggesting that spectroscopic observations of sun spots should be undertaken at the Elphinstone College at Bombay with the instruments which had recently been provided for that institution.

Solar Observatories in Italy and France on the method of observation and record of Solar phenomena, presented a Report on the subject which will be found in Appendix IV.

On consideration of M. Janssen's recommendations (which will be found in his letter annexed to Mr. Lockyer's Report), it was resolved that his suggestions were of such high value and practical character that they should be accepted as indicating the most suitable course to be followed for the further prosecution of the study of Solar Physics.

It was also resolved that the first step should be the formation of a preliminary International Committee on organisation, and the Committee expressed a hope that the Science and Art Department would obtain the necessary approval of Her Majesty's Government. The Committee, however, thought it desirable, first, to obtain the opinion of the President and Council of the Royal Society on these proposals, which in their estimation were of the highest scientific importance.

On receipt of the reply of the Royal Society, which was favourable to the contemplated action, the Science and Art Department was requested to invite the under-mentioned men of science engaged in Solar research to meet in London in order to confer with the Committee on Solar Physics with regard to the co-operation of observers in all parts of the world in Solar research, and to consider the particular proposals made by Dr. Janssen—

Dr. Bredichin.
Dr. De la Rue, F.R.S.
Dr. Huggins, F.R.S.
Dr. Janssen.
Professor Konkoly.
Rev. S. J. Perry, F.R.S.
Professor E. C. Pickering.
Professor Respighi.
Professor Ricco.
Dr. A. Schuster, F.R.S
Professor Spörer.
Professor Struve, or his delegate.
Professor Tacchini.
Dr. Thollon.
Dr. Trépied.
Dr. H. E. Vogel.
Professor Wolf.
Professor C. A. Young.

Day.	July.	August.	September.	October.	November.	December.
1	K·79, E··	K·50, E···				
2	K·50, ·51			K·51, ·55, E··	E··	
3	K·50, ·51, E···	K·50, ·54, E··	E···			
4		K·53, ···, E···	E···	E···		K·51
5		K·49, ··, E···			K·46, ·50	
6		K·54			K·52, ·53	
7	K·52, ···, E··	K·48, ···, E···		K·48, ··, E···	K·53, ·54, E···	
8	K·46, ···	K·49, E···, ··	E···	K·49, ·50, E···		K ··
9	K·66	E···			K·50, ···	K·52, ···
10	K·52, E···	K·50, ·61, E···	E···	K·50	K·51, ···, E···	K·46
11	E···		E···	E···		K·62
12		K·51, ·63, E···	K·50, ·51, E··	K·60, E··		K·51, ···
13	K·54, ···, E···			E···		
14	K·65, ···, E···	K·50, ···	K·46, ·49	K·46, ·52, E·		
15	K·51, ·52, E···	K·50, ·53, E···		E·		K·45, ···
16	K·46, ·48, E···		K·48	K·50, E··		K·50, ··
17			K·52, ·53, E···	K·49, ·52		K·51
18	K·47, ·48	K·65, E··	K·44			K·47, ··
19	E···			K·51, ·53, E···		K·51, ···
20	K·50, ·51, E···			K·51, ·54, E···	K·52, ·	
21	K·46, ·47, E···	K·64, ···	K·48, ·49	K·50, ·51, E··		
22	K·45, ·46, E···	K·50, ·51	K·45, ·62, E···	K·51, ·53, E···		K·46, ···
23			K·48, E···	K·55, ·64		K·54
24	K·44, ·52, E···	K·48, ·49	K·45, ·50, E···		K·48, ··	K·52
25	K·50, ·51, E···	K·46, ·47, E··				
26	E··	K·43, ·45	K·51	E···		
27	K·48, ·50, E···			K·49, ··, E·		
28	K·47, ·48, E···	E···		K···		
29	E··	E···	K·48, ·49, E···			
30	K·54, ·55, E···		K·54	E··		
31	K·49, ·51, E···	E···	———	K·47, ·52	———	K·47, ···

may be utilised in further inquiries, or for practical purposes.

The Committee have already secured complete photographic records of the sun's surface from the year 1881 to the present time, and they have already begun work in several directions with a view of ascertaining what increase of our knowledge we may hope to obtain from them. The Committee have arranged with the Astronomer Royal that the measurement and reduction of the solar photographs should be made at Greenwich.

On the sun the unit of change, so to speak, is not a day or a year as with us, but it is a period of about 11 years. The full meaning of each cycle of 11 years cannot be grasped unless the observations are practically continuous, and it would be an unscientific mode of procedure to assume that every cycle is like every other—indeed we know that this is not so. A break now, therefore, in observations of the present cycle would not only prevent us from securing complete observations of it, but would react detrimentally on our knowledge of all the others, because our power of comparing one cycle with another would be lost.

Further, our present knowledge leads us to see that if we content ourselves with observations of the spotted area alone we may be discarding branches of work which from some points of view are of higher importance. No study of the spotted area alone, for instance, would have demonstrated the remarkable change in the temperature of the lower strata of the solar atmosphere which has been revealed by the spectroscopic observation of both spots and prominences, and it may be that in a not distant future we may find these indications of varying temperature to be most important from a practical point of view. Bearing this in mind it is needful for us to point out that as a matter of fact the experimental study of the solar spectrum from the point of view of the origin of the Fraunhofer lines and their appearance in various solar phenomena is not being carried on anywhere else but at Kensington.

In what has gone before we have endeavoured to show how important it is that there should be neither break nor diminution in the work on which we have been asked to advise the Government.

We now pass to another point.

The Lords Commissioners of Her Majesty's Treasury appear to contemplate that the various kinds of work under-

DAY.	JULY.	AUGUST.	SEPTEMBER.	OCTOBER.	NOVEMBER.	DECEMBER.
1	W·32, ·40 K·64, · ·	W 56, ·60, E···	K·50, ···	K·48,·· ,W·50	E ··	K 55
2	W·23, K·67	K·54	K 48, ···	W 41		
3	K·62, W·66, E···		K 54, · ·		K 44, E	K 55, ··
4	E ·	W 57	W 31, K 48,·	K 54, ··	K·47,·· , E ··	
5	W·23, ·33 K·63, ···	W·35, K·51,··· E· ·	W 29, E··	K 47, ··	K 44, ·	
6	W 28	W 50, ·65, K·58	W 32, 52 K 40, · ·	K 45,·· , E ··	W 37, 39, 45 W 47, E· ·	
7		K 45,·· , E··	W·35, 38 K 45,	K·47,· , E		
8	K·62, E···		W 34, K 64,· ·	K·60, ···	E ··	
9	K·50, · , E· ·	K·48, E···	W·35, K 48, ··	K 50, ·		W 47
10	K·50, ···, E· ·	K 70,···, E ·	W 26, ·42 K 53, ··	W 43, E ··,···	K·51, E	
11	E···	E···	W 32, ·37, K 44	W 45, K·47,··· E···	K 45, · ·	
12	K·40, ···	K·47,···, E···		K·45, , E··	K·60	
13	K·49, ···, E···	K·60, ···	K·46, E···	W·42, K 56,· · E ··		
14	K·49, ···	W·56, ·59		K·43,···, E		K·48, ···
15	K·51, ···, E···		K·53, ···			K·47,· , E ·
16	K·47, E···	K·51	K 48, ··		K·48,···, E···	
17	K·48	K·47, W·65, ·67 E···	E ··	E ··		K 43,·· , E··
18	W·27	K·49, E···	K·62		K 51, ···	E ·
19	W·34, K···		E···	K·47		K 41,···, W 50 E···
20	W·30, K···, E···	E···	K·50	K 48,···, E···	K·45, ···	K·43, ··, E· ·
21	K·70	W·34, ·36, K·57 E···	K·48,···, E···	K 51, E···		
22	K·47, ···	W·26, ·33, E···	K 43, ··, E···			
23	K·51, W·61	K·49, E···	K·48,· ·, E·	W·42, ·51		K 44, ···
24	W·33, K·48,···	K·47		W·44, ·53, E···		K 54, · , E· ·
25		K·63, E···	K·51,···, E···	K·55, E ··	K 50, ·	E
26	W·16, ·40	K·65,···, E···		K·48, ·		
27	K·48,···, W·61	W·29, K·46,··· E···	E· ·	K·54, ···		
28	W·65	W·29, ·40, E··· K···, ···	K·41,···, E···			K·50 ···
29	W·40, K·51,··· E···	W·37, K·64	K·43, ···	K·51,···, E···	E···	K·46, ·· , E···
30	K·67		W·43, ·51, E···	W·44	K···, E ·	
31	W·15, E···	W·20, K·53,··· E···	——		——	

(11.) A diffraction grating by Rutherford, ruled on speculum metal. This is the property of the Department and is used with a spectroscope in which the scale is observed by a second telescope clamped above the observing telescope.

(12.) A 3-prism spectroscope by Hilger, the property of the Department. The collimator of this instrument is about 5 feet 9 inches long, and the prisms are each 3 inches deep and 6 inches edge. The dark slide used with the camera is so arranged that any part of the plate can be exposed to the spectrum; in this way several parallel spectra can be obtained by successive exposures on the same plate. The photographic lens used is a 4-inch rapid rectilinear by Dallmeyer, the focal length being about 16 inches.

(13.) Spectroscope by Hilger, the property of the Department. In this the prisms are made of Iceland spar and the lenses of quartz. There is one prism of 60° and two halves of a prism of 60°, the prism having been cut into two equal parts by a vertical section through the vertex. One of the half-prisms is placed with the rectangular face immediately in front of the collimator lens, and the other with the rectangular face in front of the object glass of the observing telescope. The observing telescope can be replaced by a camera, the lens used for photography being simply the object glass of the observing telescope.

(14.) A Steinheil spectroscope with three prisms of 30° and one of 60°, the property of the Department.

(15.) A direct-vision spectroscope mounted on a stand by Hilger, the property of the Department.

(16.) A Rowland grating spectroscope, the property of the Department. The grating is a concave one of about six feet in focal length, and has about 17,000 lines to the inch. The available surface of the grating is 5 in. × 2 in. It is mounted on a wooden frame in a hut facing the siderostat. The grating and eye-piece (or camera) are fixed one at each end of a board, the ends of which slide in a pair of grooves at right angles to each other, and the slit is fixed at the intersection of the grooves. The distance between the grating and the camera is twice the focal length of the grating-mirror, so that the slit always lies on a circle described on that line as diameter. This being the case, all the spectra are brought to a focus at the camera. In this way a normal spectrum on an invariable scale is obtained.

(17.) Star spectroscope, by Hilger, having a prism of 60° and two half prisms.

(18.) A 6-inch prism for photographing star spectra.

2. The 10-inch equatorial, with the added Gautier photoheliograph, is erected in a wooden observatory with a conical revolving dome.

3. The Greenwich photoheliograph is in the hut originally constructed for use in the Transit of Venus Expedition (1874).

4. The siderostat is in a hut running back on a tramway.

5. The Rowland grating spectroscope is in a dark hut facing the siderostat.

All these are in the spare ground behind the Exhibition Road Post Office, and are all in a fair state of repair.

(3.) *Photoheliograph.*

The new instrument, to replace that sent to India, was completed in 1885, and many photographs were taken between that year and 1886. It soon became obvious that there was something wrong about the secondary magnifier, because under very perfect observing conditions it was not possible to obtain the mottled surface of the sun in any way approaching to the perfection secured at Meudon.

Professor Stokes was consulted on this matter, and the upshot of it was that the Department authorised the construction of a new secondary magnifier by Grubb, of Dublin.

The photoheliograph was then re-erected alongside the tube of the 10-inch equatorial. Some time, however, elapsed before some of the fittings were returned from Mr. Dallmeyer, and for the next 10 weeks the sun was rarely, if ever, visible in the observatory. A long time thus elapsed before there was an opportunity of testing the instrument on the sun. In the meantime, however, the magnifier was subjected to several tests. The cross-wires of the instrument were first replaced by a piece of tin-foil pricked full of holes; then, the instrument being directed towards the sky, a photograph of the pin-holes was taken on a plate 15 inches square. Soon after, at the suggestion of Professor Stokes, the tin-foil was replaced by a piece of silvered glass on which various dots and crosses had been scratched. This proved to be better than the pricked tin-foil, because there was no reflection from the sides of the holes. To get the best definition, it was found necessary to insert a quarter-inch stop between the two lenses of the secondary magnifier.

A series of experiments were also made with the view of testing the performance of the 6-inch photographic object glass. The lens was fixed at one end of the long wooden tube which was made for the Eclipse Expedition of 1886.

Up to August 1885, 700 observations of spots had been made, and these have been reduced and the results published.* For a short account of the results, see Spectroscopic Phenomena of Sun-spots, page 8 of this Report.

Since August 1885 150 observations have been made. These have since been reduced, but have not yet been published.

The results are almost perfectly continuous with those already referred to.

Photographs of the spectra of sun-spots and prominences have been taken with a Rutherford grating. The spectroscope was attached to the eye-end of the 6-inch equatorial, and an image of the spot or prominence was formed on the slit by the object glass. On one side of the grating was the camera, and on the other side a small observing telescope, so that the spectrum could be observed whilst being photographed. The whole spectroscope was provided with a fine adjustment independent of the motion of the telescope; in this way any inequality in the motion of the clock could easily be corrected.

It was found, however, that the spot spectrum could only be focussed over a small region.

The spot spectra showed some of the lines widened, and occasionally H and K were reversed.

The prominence spectra sometimes showed H and K reversed, sometimes K alone. No metallic lines were photographed, probably because the photographs were taken at a period of quiescence.

A series of experiments has also been made on the spectra of the arc of a Siemens's machine. It was shown that not only was there a separation of the lines of different elements at the two poles, but that in some cases one set of lines would appear at one pole while other lines of the same metal were seen only at the opposite pole. Other phenomena were also observed and recorded, such as the inverse appearance of lines, in some cases one set of lines being seen alone, in other cases other lines of the same metal appearing by themselves. The various appearances of lines during reversal were also examined.

b. Fractionation Experiments.

Experiments have been made in conjunction with Professor Crookes on the fractionation of some chemical substances.

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* Proc. R.S No. 224, 1886.

or spark spectrum. Thus between wave-lengths 5,100 and 5,500, Ångström records 92 iron lines and Thalen 45; the flame spectrum only contains 8 lines for the same region. Similarly, copper gives 1 line where Ångström maps 4.

d. Spectra of Carbon Compounds.

An extensive series of experiments have been made on the spectrum of carbon. Since the commencement of the research in 1880 over a thousand photographs of the spectra of various compounds of carbon under different conditions of temperature and pressure have been obtained; of these between two and three hundred have been kept as reference photographs.

The general method employed for obtaining the spectra has been to use flames, or to enclose the gases or vapours in glass tubes provided with platinum points, and to illuminate them by electric discharges from an induction coil.

Different kinds of tubes were used, giving spark discharges varying in length from a quarter of an inch to twelve inches, and in diameter from an inch to one fortieth of an inch. The tubes were usually of a compound form so that different conditions could be obtained without the necessity of charging the tube each time. The end of the tube nearest to the spectroscope was provided with a clear bulb, so that when placed in a line with the collimator, light from every part of the spark passed through the slit.

One end of the tube was connected with a Sprengel pump, and the other with an apparatus for preparing the gas or vapour the spectrum of which was to be examined. All the joints and stop-cocks were made perfectly air-tight by surrounding them with mercury and glycerine.

The whole apparatus was first exhausted as far as possible, and was then filled with gas. This was again pumped out and the tube re-filled, and so on until the gas was perfectly free from air. Whilst this process of washing out was going on the tube was kept constantly heated, so that air and moisture could not adhere to it. Photographs were usually taken during the process of purification in order to ascertain the effect of a small quantity of air or other residual gases upon the spectrum.

When flames were used, the jet was placed about two feet from the slit and an image was focussed on the slit by a lens. The spectroscope employed was one by Hilger, in which the collimator is about 5 feet long, and the camera adapted for quarter plates. As a rule, only one prism was used.

current is being started or broken, there occur three sets of flutings which have not been recorded by other observers. Unlike those occurring in the arc spectrum, these flutings shade off towards the red.

c. Spectra of Stars, with special reference to Carbon.

Having obtained some two or three hundred reference photographs of carbon spectra under known conditions of temperature and pressure, we are now prepared to undertake an investigation of the nature of the carbon which is known to exist in many of the stars.

It is proposed to get comparisons of the star spectra with the spectrum of a known carbon compound enclosed in a Geissler tube. The Geissler tube will be placed in front of the object glass and a small lens will be introduced to render the rays of light from the tube parallel to each other. The Geissler tube will thus be focussed on the slit at the same time that a star is focussed. The tube being placed parallel to the slit, the spectrum of the carbon compound enclosed in it will have a width equivalent to the length of the slit. The image of the star will be allowed to travel over only a small portion of the slit. In this way a double spectrum will be obtained—the spectrum of the star superposed upon the much wider spectrum of the Geissler tube. Any coincidences will be marked by an increased intensity in the flutings composing the spectrum of the Geissler tube where crossed by the star spectrum.

The preliminary trials of this method have not proved very satisfactory, probably because the object glass of the telescope did not give a photographic image on the slit. The spectroscope employed was one in which the prism was made of Iceland spar.

Experiments have also been made with the view of using a diffraction grating for star spectra. The grating, ruled on silvered glass, was placed inside the principal focus of the object glass, so that when the telescope was pointed to a star, the star was focussed after reflection from the surface of the grating. In this way the spectrum could be obtained without the use of any lens except the object glass. The photographic plate was placed at a distance from the grating equal to the distance of the grating from the principal focus. The spectrum thus obtained, however, would be without width; the necessary width was obtained by adjusting the grating so that the lines were parallel to the equator of the telescope, and allowing the clock to travel a little too slow or a

"Researches on the Spectra of Meteorites." Received 4th October 1887. Addendum. Received 15th November 1887.

"Suggestions on the Classification of the various Species of Heavenly Bodies." (Bakerian Lecture.) Received 21st March 1888.

"On the Spectra of Meteoric Swarms in the Solar System." Received 22nd November 1888.

"On some Effects produced by the Fall of Meteorites on the Earth." Received 22nd November 1888.

"Suggestions on the Origin of Binary and Multiple Systems." Received 22nd November 1888.

"On the Spectrum of Saturn's Rings." Received 7th February 1889.

"On the Spectra of Meteor Swarms." (Group III.) Received February .

10. The rehearsal on the day before the eclipse should be a complete rehearsal, with photographic plates exactly as during the eclipse itself, and these plates to be developed at once and brought home.

11. The observers should confer with the American astronomer in charge regarding time signals before and after totality.

12. If additional observing power can be obtained from the American party, the additional observers to be trained to obtain photographs with the photoheliographs, and if desirable, the time-table for that instrument to be handed over to them, they being placed in entire charge of that part of the operations.

13. If such assistance cannot be afforded, then, if the photoheliograph programme cannot be carried out in its entirety, the large pictures to be alone attempted.

14 Special attention to the rating of the clocks, including the eclipse clock and siderostat, to be given at least three days before the eclipse.

15. A quarter of an hour before totality, clocks to be wound, and caps and stops, which had hitherto been used to diminish the amount of light, to be removed if necessary.

16. The timekeeper should be asked to give these instructions in a loud voice, as experience has shown that they are apt to be forgotten.

17. In the observations and adjustments during the eclipse no deviations from the time-table and adjustments to be made except after consultation and with the approval of the American astronomer in charge.

18. The clockwork of the integrating spectroscope to be so adjusted that the plate will fall through 1 inch in 8 minutes.

19. The distance of plate from concave grating to be that given by Captain Abney for vertical distortion.

20. In equatorial the slits to be parallel and vertical in the meridian and their centres lying on the same part of the sun.

21. All the slits to be $\frac{1}{500}$ in. = No. 2 on Captain Abney's screw, with the exception of the integrating spectroscopes which should be $\frac{1}{250}$ in.

22. At some convenient time, say 100 seconds, near the middle of totality the slits of equatorial to be brought to the point of re-appearance,

Code for Cypher Telegram.

Very good.	*Good.*	*Indifferent.*	*Bad.*	*Very bad.*
Bad	bell	bird	bog	bust
Can	cent	cinder	cow	cut
Day	den	dip	dog	dust
Far	fetch	fig	frog	fun
Gas	get	gill	gold	gum
Hall	hen	hit	hold	hunt
Kappa	keg	king	Koch	Kuhne
Lamb	length	light	lot	lump
Mad	mess	mint	most	muff
Nag	nest	night	now	nut
Pan	pelt	pig	port	pull
Rag	rent	right	rot	rust
Sap	sell	sing	sort	sum
Tar	tent	tin	told	tug

B = 6 prism on equatorial.
C = double grating on equatorial.
D = dense prism on portion of 6-inch equatorial
F = Integrating Hilger.
G = Red end slit.
H = Red end prismatic camera.
K = 1st order blue Rowland.
L = 2nd „ „ „
M = 4-inch photoheliograph.
N = small „
P =
R =
S =
T =

FORM FOR RECORDING OBSERVATIONS.

Day	July	August	September	October	November	December
1			G 16,	G 15, 47, W 48		
2	G 16, 17		W 35, G 11, 19	W 84	O 66	
3	G 52, 53, W 67	G 13, 41 W 11, 50		G 11, 17, W 16	W 39, 50 G 55,	G
4	G 50, W 67	W 38	G 57, 57	W 59	G 49, O 69	G 41,
5	W 33, 35	W 63	G 10, 11	G 15, 50	G 17, 52	W 42
6	G 49, 60	G 42, 16			G 56, 59, O 65	
7	G 15, 16				G 16, 19, O 59	G 44, 16
8	W 30, 31 G 50, 52	G 41, 17		G 50, 52		
9	G 52, 53	W 12	W 31, G 60, 62		G 58	O 70
10	W 30, G 50, 51	G 13, W 37, 39	G 12, 15, W 16	G 39, 11, , G , , ,	O 67	
11		G 43, 57			G 47, O 61	G 15, 50
12	W 36, 37	G 13, 46	G 13, 11		G 12, 44, O 68	O 71
13	W 35, G 54, 56			G 17, 51	G 10, 49, O 67	
14	G 51, 52	W 37, 38 G 49, 51	G 13, 19		O 67	G 46, 53
15	G 14, 45	G 13,	G 16, 16	G 51, 56		
16	G 51, 53,		W 52	W 50, 51	W 51, G 51 O 72	
17	G 51, 53	G 18, , W 34	W 18	W 17, 50	G 57	G 58, 59
18	G 50, 52,				O 69	G 51, 52
19		G 50, 50	G 15,	G 52, 58	O 78	
20	G 51, 52, W 34	W 53, G 56,		W 17, G 50	G 14, 54,	
21	W 27, 29, G 50	G 49, 54	W 18	O	O 65	
22		G 41, 51	G 51, 50, W 16	G 55, , O		
23	G 50, 51, G ,		W 56	G 49, 53, O	G 45, 47,	
24	W 27, 29, G 56	G 41, 59	G 40, 13, W 12	O 78	G 51, O 61	
25	G 14, 48	G 45, 16	G 42, 19		W 42, O 65	
26		G 12, 43	G 47, 59	O 73, G		
27		G 47, 51		G	G 40, 57, , O 68	
28	W 41	W 31, G 42, 44	G 47, 58	G 52, 51, O 69		
29		G 50, 52	G 50, 53	G		
30	W 36, 38 G 15, 16		G 17, 49	W 17, O 73, 78		
31	G 10, 44	G 47, 40	——		——	

APPENDIX III.

Tabulation of Sun-spot Data.

(1.) *Report of the Astronomer Royal and Professor Balfour Stewart on the best Method of tabulating the Sun-spot Data now available.*

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1. In a Catalogue of solar pictures and photographs forming an Appendix to the Report of the Solar Physics Committee will be found a nearly complete specification of the material available for the purpose of carrying into effect the first recommendation of that Report, which advocates the importance of collecting and publishing the existing information regarding sun spots.

2. In order to render the reduction and publication of this back work as useful as possible, two things would appear to be necessary.

In the first place the record should be rendered as complete as possible by means of the contributions which the directors of the various solar observatories have kindly undertaken to give; and, *in the second place,* the Committee should endeavour to obtain a numerical estimate of the accuracy of the various contributions which they hope to receive.

3. For this latter purpose it will be desirable to regard the Kew series while it lasts, and after it the Greenwich series, to both of which easy access may be had, as standards with which a certain number of comparisons should be made in the case of each observatory. As regards the estimate of accuracy of the results obtained at these standard observatories, it is to be remarked that both in the Kew and Greenwich series there is a large number of days on which two photographs have been measured, and a simple comparison of the results would give the desired information. Thus each solar observatory will be asked to contribute information for certain days when there was no photograph taken at Kew or Greenwich; and also a small additional amount of such information for certain days when photographs were taken at Kew or Greenwich with the view of comparison with these pictures.

As there are several solar establishments it is hoped that the call made upon any one of them will not be found very burdensome.

Year.	Greenwich.	Other Observatories.	Total.
1873 - -	64	178 C., W., & E.	242
1874 - -	163	63 C , W., & E.	226
1875 - -	161	128 C., W., Ma , Me., Mo.	289
1876 - -	163	150 C., W., Ma., Me , Mo.	313
1877 - -	169	117 C., W., Ma , Me., Mo.	286

We now proceed to discuss the various series of observations.

Schwabe's Observations.

8. In the Catalogue already referred to there will be found recorded under their appropriate dates the total spotted area for each day when Schwabe took a sun picture, these results extending without interruption from the beginning of 1832 to the end of 1853. Besides this continuous series for which Schwabe was the sole observer, it will be found from the Catalogue that certain pictures of Schwabe's are coincident in point of time with certain pictures of the Redhill and of the Kew series. Means thus exists for determining the numerical accuracy of Schwabe's pictures, and it seems desirable that such a determination should be made.

Redhill Series.

9. In his publication entitled 'Observations of the Spots on the Sun, from November 9, 1853, to March 24, 1861", Carrington has given a detailed account of his method of observation, and has exhibited the heliographic positions of the various spots observed by him on the sun's surface.

Carrington's pictures were accurate sketches from eye observation, and not photographic records. Nevertheless, as there are a few days on which pictures by Carrington, and photographs at Kew were taken simultaneously, it would be desirable to endeavour to obtain from these simultaneous records a numerical estimate of the value of Carrington's observations.

10. The positions given by Carrington are not those of the centres of mass of the various groups, but of the individual members of each group. It will therefore be necessary to obtain the former from the latter. This may be easily done,

positions at all. This information would only be of service for such groups as are not recorded at all in the Kew pictures, if there be any such. For these reductions it will be necessary to obtain the loan of the Ely pictures from the Royal Society.

Kew Photographs.

15. Mr. De La Rue has obtained determinations of the areas of each Kew group of sun-spots. He has likewise caused a certain proportion of these areas to be remeasured. This will give the means of estimating numerically the precision of these area determinations.

16. Mr. De La Rue has recently presented to the Royal Society the heliographic positions of each spot of each Kew group along with a classification of these into ten relative magnitudes. It will be necessary for the purposes of the Solar Physics Committee that from this MS. the heliographic positions and relative magnitudes of each individual member should be brought together for each sun-spot group, then weighting each member according to its relative magnitude, the positions of the centres of mass of whole groups might be determined with sufficient accuracy to suit the objects of the Committee.

It would be desirable to remeasure and recalculate the positions of a certain number of the Kew groups (if this has not been done) in order to be able to estimate numerically the precision of these determinations.

Photographs of other Observatories.

17. It frequently happens that on days when no picture can be taken at Kew or Greenwich pictures have nevertheless been taken at other places.

It will be necessary in such cases to make use of the good offices of the directors of these observatories in order to render the catalogue complete.

The most suitable principle in making such applications would be not to lay an excessive burden upon any one institution, but to distribute the work required in an equable manner amongst them all.

18. It would, however, be extremely desirable for those days which are blank for Kew or Greenwich to have measurements of areas from two different stations if possible—more than two would be superfluous.

With regards to positions the measurements of these from a single station would suffice.

The areas and positions of the various groups of the Greenwich series are already published.

The Astronomer Royal would undertake to furnish such tracings of certain of the Greenwich pictures as it may be necessary to send abroad for the purposes herein indicated.

Suggested Mode of Procedure.

23. It is suggested that the following steps should be taken:—

(1.) The Committee should communicate with the Directors of Solar Observatories, sending them a copy of this Report, and requesting from them a list as before of their sun pictures between the end of 1877 and the beginning of 1882. A further communication should then be addressed to each Director asking him to supply the areas and positions of sun spots and faculæ from the photographs in his possession for days specified in accordance with paragraph 15 of this Report; or in case of his not being able to undertake the work to supply the Committee with materials for doing it themselves.

(The position-angles and distances from the sun's centre of spots and faculæ may be measured with sufficient accuracy by means of a glass plate ruled with concentric circles at a distance of $\frac{1}{20}$ of the sun's radius apart, every fifth circle being thicker, the 18th circle being divided into degrees, with cross lines through the centre to the four cardinal points 0°, 90°, 180°, and 270°.)

(2.) The Indian photographs from the beginning of 1878 to the end of 1881 should be measured in duplicate for those days on which there are no photographs at Greenwich. This work has been commenced by Mr. Lawrence. It will probably occupy the whole time of one person for 15 months.

(3.) Application should be made by the Committee for the loan of the Kew series of photographs, of the Ely series, of Carrington's original drawings, and of the measures of areas from these drawings made by Messrs. De La Rue, Stewart, and Loewy, with a view to a remeasurement either in whole or in part of the areas of spots and the measurement of faculæ. This work might be commenced after the completion of the measurement of the Indian series.

The following is a list of the dates of the photographs containing spots which will fill gaps in the Greenwich-Indian-Mauritius series:—

1878. Jan. 25, 26. June 1, 5.
1879. Feb. 15. April 22, 23. May 9. July 1, 3, Oct. 8.
1880. Jan. 9. Feb. 10, 14, 16. Mar. 22. April 22. June 14, 25. July 6, 16, 17, 28. Aug. 6, 16. Nov. 18. Dec. 28.
1881. Feb. 22. Mar. 26. June 5. July 7, 20, 23, 27. Sept. 3. Nov. 30. Dec. 29.
1882. Jan 31.
1883. Jan. 24. July 17, 18, 23. Aug. 4, 6, 29. Sept. 6. Dec. 1, 3, 31.
1884. Feb. 19, 28. Mar. 4, 13. May 20. June 2, 5, 18, 19. July 1, 6, 7, 13, 15, 16, 23. Sept. 1, 14, 26, 29. Oct. 1, 24. Nov. 27, 30. Dec. 23.

The measurements and reductions have been completed for all these, with the exception of five (1883, July 17, 18, 23, Aug. 4 and 6), which seem to have been wrongly dated. The mistake could probably be rectified by comparison with the Greenwich—Indian Series. These have been omitted from the reductions.

In these photographs the cross-wires are at angles of 45° to N. and S. points.

(5.) *Sydney Photographs.*

There are 146 photographs from Sydney for the year 1881 and 17 for the year 1882. An examination of the photographs and dates shows that five of those for 1881 were taken on days for which there are no other photographs. The dates of these are as follow:—

1881. June 7, July 8, 22. August 31. September 2.

These photographs have only one cross-wire and are all unvarnished. The cross-wire is out of focus and the limb is ill-defined in every case, it has therefore been impossible to make measures of any real value.

(6.) *Lisbon Photographs.*

Since the year 1878, the date up to which the list of photographs was made in the last report, only 12 photographs have been received from Lisbon. The dates are as follow:—

1880. May 30. June 2, 23, 24, 25, 26, 27. Sept. 15, 30. Oct. 1, 2, 3.

JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
	Ma 19 21 Mo 28	G 15 56	G 11	Me 07 Ma 18 G 13 16	Ma 17
Mo 30	Me 22 G 51, 53 Ma 22, 24		Me 07 G	Ma 17 19 Mo 13	G 51 53 Ma 17
Mo 11 G 13 15 Mo 31	Me 05 G 50 51 Mo 30		Me 05 G ,	Ma 17, 18 G 48 49	Me 08 Ma 18
Me 20, G 13, 14 Mo 20	Mo 08	Ma 20, Mo 31 G 19 51,	Me 09	Ma 18, Me 19 G 49 50	Ma 17
Mo 11 G 10 11		Me 06 G 30 56 Ma 21	Me 09 G 10 14	G 11 Ma 10	Me 09
		Me 20 G 10 17 Mo 34	G 10 18	Ma 18	Me 11
G ,	Me 06	G 30		Me 07 Ma 17	Me 08
		Ma 20	G	Me 07, G 14,	G ,
Mo 21	Me 06 G	Ma 18 G 50 53	G		
Mo 10 G 11, 16			Me 07	Me 05 G 14	Me 10
Mo 10		Ma 19	Me 07 G		Me 08
Mo 09, G 19	G	G 10 11 Ma 20	Me 07 G ,	Me 21, G 10 18	G
G ,		Ma 19 Mo 13		Me 05	Me 12 G
Mo 06	Me 11 G 16 50	Ma 19		G 18 51 Me 09	Me 11
		Ma 19	G	Ma 17	
	G		G	Me 06, G 55	
Mo 13 Ma 21 Mo 17	Me 08, G , ,	Me 08 Ma 50	G 12 13	Me 08 Ma 18 G 56 61	Me 11
G 16, 18	G ,	Me 08, G 52, 53	G ,		Me 20 G
		Ma 20, 22 Me 09		Me 08	
Me 21 G 51, 53	G ,	Me 11	Me 09 G ,	Me 09, G ,	
Me 09, G 50, 52	G	G 11, 51		Me 13	Me 10
	G 18, 53	G , ,		G 49 52 Me 19	
Mo 07	G 10, 58		Me 09	G 12, 15,	
Mo 11, G	Ma 19 22 G 13, 15	G 30, 11	Me 07 G 30, 50	Me 10	
G ,	Mo 11	Mo 08	Me 07	Ma 18 Me 22	
Mo 08, G	Ma 18, Mo 35	Ma 10, G 50		Me 11 Ma 17 G 54 56	G
	Ma 20, 22 Mo 10	Me 09, G 10, 51	Ma 20	Ma 17 Me 22	Me 09 G
	Ma 20, G 17, 48	G 11	Ma 21	Ma 16, G 15, 19 Me 08, 13	G
G ,	G 56, 58	Ma 20, G 51, 53	Ma 19	Me 09, Ma 17	Me 07
Me 07, G 11 12			Ma 17 20 18 G 51,	Ma 17, G 11, 15	
Mo 07, G 10, 12	G 10, 11, Mo 48	———	Me 06, Ma 17 G 14, 15,	———	G 16 18

A group is represented as a single spot, the latitude and longitude being taken as the centre of gravity of the group.

In the Greenwich Spectroscopic and Photographic Results for 1886 and subsequent years the areas and positions of spot-groups are collated for the several days on which the group was visible, and the area and mean longitude of the group are formed with a view of facilitating discussions of the changes from day to day in a spot-group and the recognition of those regions of the sun where spots form most frequently.

The following lists, &c. have been prepared in connexion with the work done on the globe :—

1. A list showing the mean areas of umbræ whole spots and facular upon the sun's disc for each rotation of the sun from July 28, 1883, to December 30, 1884.
2. A table showing the history of a group of sun-spots in the southern hemisphere in June 1880.
3. List of spot-groups over 500 in area which are within 7° longitude of each other, and having + latitudes (from 1880 to 1884).
4. List of spot-groups over 500 in area which are within 7° longitude of each other, and having — latitudes (from 1880 to 1884).

(These lists give group, number, date, longitude, latitude, and direction of motion.)

5. List of spot-groups over 500 in area in order of longitude and having + latitudes (years 1880 to 1884).
6. List of spot-groups over 500 in area in order of longitude and having — latitudes (years 1880 to 1884).
7. List of spot-groups over 500 in area within 5° longitude and two months' interval, giving the date, longitude, latitude, direction of motion, amount of motion in degrees, the number of days in which that motion takes place, and the velocity in miles per day.
8. List giving the mean heliographic latitude and mean distance from the equator of the spots upon the sun's disc for each rotation between April 27, 1874, and December 3, 1884. (This list was prepared at Greenwich.)
9. List of the velocities of currents carrying spot material, giving the number of the group and the velocity for those occurring in 1880.
10. Tables giving date, time, number of group.

formal proposal from the Minister, and that they had at once approved of this proposal, and agreed to provide for the necessary increase in expenditure. Chapter XIV. of the estimates of Public Instruction was then voted, with the proposed increase Since then, a sum of 50,000 francs (2,000*l.*) has appeared yearly in Chapter XIV. of the estimates for Public Instruction for the expenditure on the Observatory of Astronomical Physics; this sum has been raised to 65,000 francs (2,600*l.*) in the proposed budget for 1880.

Such is the origin of the Bill now before us, which purports to secure a portion of the domain of Meudon for the Observatory of Astronomical Physics, and obtain a vote for it.

The discussions which have taken place in the National Assembly render it unnecessary to enter into details as to the grounds on which this Bill has been brought forward It may not, however, be useless to advert to the reasons stated before the House by the author of the original amendment, and referred to by M. Lepère, in support of the creation of the new Observatory.

Astronomical science was, first of all, based upon Geometry, and later on Mechanics; in the domain of these two sciences, in the first place, Physics made an inroad, especially at the beginning of the century, thanks principally to Arago; and then Chemistry, owing to M. Kirchhoff's discovery, which enables the substances which exist in the stars to be analysed by means of the light which they send us. To a French man of science who does honour to his country, we owe the opening up of a fresh field to Solar Astronomy, viz., that of spectroscopic study. M Janssen has invented the methods now used by men of science throughout the world.

On returning from his mission to Japan, he would not have found any shelter in France for his instruments, had not the Parc of Meudon been provisionally placed at his disposal

Whilst his fruitful methods are applied in England, in the United States, in Germany, in Italy, our illustrious countryman would have been unable himself to apply them, and to continue those researches which, matured in his mind, and destined to secure fresh triumphs to science, would have become the prey of foreign workers

If, as M. Faye said in his report, submitted on behalf of the Academy of Sciences, the scientific reputation of France required in 1875 that a sum should be provided to enable M Janssen to continue his studies, this requirement is now still more forcibly and urgently felt with regard to the definitive creation of an observatory.

The most wonderful discovery, we read in the report, and certainly the most unexpected one among those for which science is indebted to spectroscopy, after the chemical analysis of the sun due to M. Kirchhoff, is that by means of which we are able to see and follow, in the full light of the sun, the grand phenomena which take place, but which hitherto had been hidden from us by the very brilliancy of its rays. In the course of an astronomical expedition with which he had been entrusted by the Academy and the Bureau des Longitudes, in 1868, M. Janssen succeeded, thanks to a judicious use of the spectroscope, in discovering this method, thus opening up to solar astronomy a perfectly new field of research. The lead was at once eagerly followed alike by Germans, English, Americans, and Italians, and unhoped for discoveries were made.

This branch of spectroscopy has formed the subject of special study in England and in Italy; it has its own publications and private establishments for carrying on researches of which the initiative was due to our countryman.

Date.			Greenwich Civil Time.		Day of Year and decimal of Day.
		d.	*h.*	*m.*	*d.*
1883	April	13	14	12,24	102·6127
	May	10	20	32,80	129·8561
	June	7	1	34,09	157·0653
	July	4	6	18,55	184·2629
	July	31	11	19,37	211·4718
	August	27	16	58,20	238·7071
	September	23	23	19,07	265·9716
	October	21	6	13,08	293·2591
	November	17	13	30,32	320·5627
	December	14	21	8,23	347·8807
1884	January	11	5	7,53	10·2136
	February	7	13	19,87	37·5555
	March	5	21	20,51	64·8892
	April	2	4	37,57	92·1928
	April	29	10	51,74	119·4526
	May	26	16	8,72	146·6727
	June	22	20	55,40	173·8718
	July	20	1	46,25	201·0738
	August	16	7	8,80	228·2978
	September	12	13	13,95	255·5514
	October	9	19	56,68	282·8310
	November	6	3	5,85	310·1291
	December	3	10	35,69	337·4414
	December	30	18	26,83	364·7686
1885	January	27	2	36,07	26·1084
	February	23	10	44,98	53·4479
	March	22	18	22,35	80·7656
	April	19	1	1,74	108·0429
	May	16	6	38,64	135·2768
	June	12	11	32,98	162·4812
	July	9	16	18,21	189·6793
	August	5	21	26,08	216·8931
	September	2	3	14,51	244·1351
	September	29	9	43,97	271·4055
	October	26	16	43,99	298·6972
	November	23	0	5,95	326·0041

Date.			Greenwich Civil Time.		Day of Year and decimal of Day.
		d.	*h.*	*m.*	*d.*
1885	December	20	7	48,64	353·3255
1886	January	16	15	51,92	15·6611
	February	13	0	4,09	43·0028
	March	12	7	57,67	70·3317
	April	8	15	1,80	97·6262
	May	5	21	2,19	124·8765
	June	2	2	9,84	152·0902
	June	29	6	51,61	179·2879
	July	26	11	50,60	206·4935
	August	22	17	22,25	233·7238
	September	18	23	36,47	260·9837
	October	16	6	25,83	288·2679
	November	12	13	39,66	315·5692
	December	9	21	13,91	342·8847
1887	January	6	5	9,53	5·2150
	February	2	13	20,70	32·5560
	March	1	21	25,44	59·8927
	March	29	4	52,00	87·2028
	April	25	11	17,18	114·4705
	May	22	16	42,97	141·6965
	June	18	21	32,54	168·8976
	July	16	2	20,35	196·0975
	August	12	7	36,13	223·3168
	September	8	13	33,79	250·5651
	October	5	20	10,71	277·8408
	November	2	3	15,95	305·1361
	November	29	10	42,37	332·4461
	December	26	18	29,86	359·7707
1888	January	23	2	36,96	22·1090
	February	19	10	48,03	49·4500
	March	17	18	33,21	76·7731
	April	14	1	23,80	104·0582
	May	11	7	10,37	131·2991
	June	7	12	10,34	158·5072
	July	4	16	54,63	185·7046
	July	31	21	56,58	212·9143

escape the glare of gaslight, and the tremulous motion caused by the passing of carriages and trains. On the terraces instruments can be placed under the most favourable conditions, being sheltered from the wind, whilst they can at the same time command that portion of the heavens which is the most explored.

Your Commission agree with the Minister that, as stated in his Bill, it would be impossible to find in the neighbourhood of Paris a more thoroughly suitable place.

We now come to the question of the adaptation of the ruins of the Château to the erection of an observatory of astronomical physics

When the Château de Meudon was burnt, the upper portions of the building suffered most. The entresol and ground floor, which were the last to take fire, were infinitely less injured, and can be more easily repaired. A complete restoration would cost two or three millions of francs, (from 8,000*l.* to 12,000*l.*,) whereas a partial one, as proposed, with the adaptation of the establishment to the purposes of an observatory, would be very much less costly. In the latter case it is proposed only to retain such portions of the Château as can be easily restored, *i.e.*, the ground floor and entresol, and to surmount this building with a terrace on which would be placed the great dome and the instruments for taking celestial observations.

The façades of the central pavillion being thus preserved would surround the great dome of the terrace, whilst the terrace of the building would be set apart for the observations; the lower portion, including the ground floor and entresol, would afford the necessary accommodation for the lecture rooms, library, calculating rooms, &c.

Whilst approving the plan of the architect, it is the wish of the Commission that the restoration should extend not only to the façade of the central pavilion, but also to the two bays, which would add to its breadth. A central pavilion of greater breadth would, the Commission unanimously think, give a more elegant appearance to the restored Château, and would secure to this work of Mansart a greater regularity of shape The central pavilion alone would not be wide enough, and would be out of proportion to the length of the two wings. This modification would no doubt cause an increase in the cost, but it would not be considerable, and the Commission have no hesitation in recommending Government to take into consideration the wish they have expressed, inasmuch as the adoption of this measure will be the means of preserving more effectively the original characteristics and architectural elegance of the building.

The Bill proposes that the private park should be set apart for the Observatory; this portion of the domain is completely enclosed by walls; it comprises, besides a large extent of land, the outhouses, orangery, &c.

The whole of the park will be required for the Observatory; for the deductions of physical astronomy are based on physical experiments which have often to be made on a vast scale; it will therefore be necessary to be able to lay down in the park, which is quite large enough for the purpose, tubes from 100 to 500 metres long, intended for the optical study of aqueous vapour, oxygen, &c.

It should also be stated that in these days extensive sites are indispensable for carrying on observations, owing to the absolute necessity of securing for the latter a sufficiently large space entirely unexposed to artificial light, or vibration of the ground. Thus the

The scheme which had been foreshadowed by Professor Tacchini was discussed and agreed to, so far as M. Thollon was concerned, with the proviso, that it could not be commenced until a research on the Telluric lines, on which M. Thollon is now engaged, was completed.

While I was at Nice M. Thollon was engaged, among other matters, on a series of observations begun last autumn at the observatory of the Pic du Midi, which is being erected by the French Government for the use of the astronomers of France and other countries in the summer months. On the summit, at the height of about 10,000 feet, he found that at the moment of sunrise, and for one and a half hour afterwards, the definition of the sun was so perfect that the hydrogen surrounding each of the domes which Dr. Janssen has succeeded in photographing could be easily observed on the C. line; so that on moving the slit of the spectroscope along the sun, the C. line was no longer continuous, but was really built up of a series of sections of a mottled surface. This I observed many years ago during London fogs, but such observations have not been recorded elsewhere, so far as I can remember, until MM. Thollon and Trepied observed them on the Pic du Midi. M. Thollon finds at Nice that the time during which these delicate phenomena remain visible after sunrise is restricted with reference to the Pic du Midi. Indeed, at least sometimes half an hour after sunrise they had almost vanished in consequence of the disturbed state of the air. The moral of these observations, as it appears to me, is that we want a horizontal photoheliograph somewhere, the higher the better, to take a photograph of the sun on a large scale as soon as possible after sunrise each clear morning, and that the more delicate spectroscopic observations should be attempted at the same time.

M. Perrotin, the director of the observatory at Nice, discussed with me as to the best means of carrying on the stellar researches which they propose to inaugurate. M. Thollon had proposed a plan of facilitating the observations by means of mirrors. It is not necessary to give the exact details. I pointed out, however, that what we really wanted was, above all things, light, and that the time had now arrived when eye observations should give way to photographic ones, and that if this principle were accepted the half million francs or more which would be required for the observatory would be saved. The conversation ended by my suggesting an 8-feet mirror of from 40 to 60 feet focal length, with a skeleton tube, merely adapted for carrying a spectroscope and camera, the exposures in either case being

The expenditure for purchase of instruments comprises a sum of 250,000 francs (10,000*l.*) for the astronomical telescope

Three years ago, when this estimate was prepared, M. Janssen intended to have constructed in France a telescope with an object glass of a diameter of about 60 centimetres, it would now, however, be desirable to increase the diameter.

Your Commission, having heard that an astronomical telescope of 80 centimetres is being constructed for the Observatory of Russia would be glad to see our future observatory at Meudon furnished with as powerful a telescope as French industry can produce. It must not be forgotten that for too long a time past astronomy has not been flourishing in France; that owing to the paucity of orders for powerful instruments our makers have had to turn their attention in other directions, and that, if we do not wish to witness the transfer to foreign countries of a branch of industry which used to prosper so well in France, it would be well to promote its revival by providing it with work Although we may not hope to at once reinstate France in this respect in the first class position she occupied, it is our duty to take advantage of every opportunity that may occur to revive a branch of industry which is so closely connected with the progress of science itself.

The cost of the revolving dome, which will be constructed in accordance with the views of the Director of the Observatory, is estimated at 49,000 francs (1,960*l.*); this, with a sum of 155,000 francs (6,200*l.*) for various instruments, 24,000 francs (960*l.*) for contingencies, and 38,000 francs (1,520*l.*) for laboratory fittings, make up a total estimated expenditure of 1,035,000 francs (41,400*l.*)

Among the new apparatus and laboratory expenses are included the requirements incidental to photography The Universal Exhibition contained specimens of photographic pictures of the sun obtained by M Janssen, which were a source of attraction and interest to the scientific world These specimens are the result of perfectly new processes due to the Director of the Meudon Observatory; they show with remarkable distinctness the granulations of the photosphere, which had not hitherto been obtained by photography. The study of these granulations, begun by M Janssen, renders it possible to foresee considerable progress in the knowledge of the solar surface and of the composition of the photosphere, a progress of which we shall secure the priority to our country if we afford to M Janssen the possibility of following it by supplying him with more powerful means.

To sum up, Gentlemen, the items proposed are as under.

	fr.		£
Repairs and appropriation of the ruins of the Château - - - - -	422,000	or	16,880
Repairs of outhouses and enclosures - -	97,000		3,880
Laboratory fittings - - - - -	38,000		1,520
Dome of the telescope - - - -	49,000		1,960
Astronomical telescope - - - -	250,000		10,000
Various physical and astronomical instruments - - - - - -	155,000		6,200
Contingencies - - - -	24,000		960
Together -	1,035,000	or	41,400

(3.) *M. Janssen's Scheme.*

(*Translation.*)

SIR,

The English Committee on Solar Physics has honoured me by asking my opinion on the methods likely to promote the progress of the solar studies with which your Committee deals.

I would have answered your invitation sooner had it not been for my desire to examine more thoroughly a subject of study which is common to us. But Mr. Lockyer's visit to Paris, and the special invitation which that *savant* addressed to me on your behalf, have determined me to send to you at once the result of my reflections on this matter.

After much reflection on the methods now employed in studying the surface and the edges of the sun, either by means of the eye, of photography, or of the spectroscope, I am more than ever convinced that these labours, which derive their value from the uniform and continuous nature of the observations, can no longer comply with the demands of science without the establishment of a concert or union between the observers.

With the admirable means of study available in photography and the spectroscope, we can only succeed in producing isolated series, disconnected, and with gaps which deprive them of nearly all their value.

What is true for the labours themselves is still more so for their publication. Every one publishes according to his means and his ideas of the object to be attained. Hence publications dissimilar both in size and method.

It therefore seems to me that the time has decidedly come when observers, who deal with regular observations of the sun, should combine their efforts and regulate their labours. This object would be attained by forming a Committee, to be termed "the International Committee on Solar Studies." Its mission would be to examine the best methods of observation, to promote their application, to establish a uniform plan of observations, and finally to collect them.

Observations.—The Committee, after investigating the existing elements of study due to participating institutions and observers, could make out a scheme of observations in which each one would have the part accepted by him, and suitable to his tastes, his acquirements, and his means.

This plan would comprise ocular, spectroscopic, and photographic observations. The Committee would en-

"Are of opinion that the vote applied for is justified by the importance of the object in view, and that the funds available in the estimates for 1879 admit of the taking of the first yearly instalment of 345,000 francs (13,800*l.*) in those estimates."

We have therefore the honour of proposing for your sanction the following Bill:

BILL.

Article I.

The Château de Meudon, the outhouses of the said château, the orangery, &c., with the portion of the private park shown in vermillion on the annexed plan, and the "Avenue de Belleville," shall be appropriated to the installation of the Observatory of Astronomical Physics of Paris instituted by decree of the 6th September 1875, in execution of the order to carry out the objects of the financial law of the 3rd August preceding.

Article II.

The cost of repairing the buildings and adapting the enclosures of the park appropriated to the Observatory, together with the purchase of instruments and fittings, will amount to one million thirty-five thousand francs (1,035,000 fr., 41,400*l.*), a third of which shall be taken in each of the estimates for 1879, 1880, and 1881.

Of this sum, four hundred and sixty-seven thousand francs (467,000 fr., 18,680*l.*) shall be borne on the estimates of the Ministry of Public Instruction, Worship, and the Fine Arts, and five hundred and sixty-eight thousand francs (568,000 fr., 22,720*l.*) on the estimates for the Ministry of Public Works.

The expenditure for the maintenance of the private park is estimated at fifteen thousand francs (15,000 fr., 600*l.*) a year. An equal sum is allowed to the Observatory as an increase to its annual estimates. These sums will be inserted in the annual grants.

Article III.

A vote for one hundred and thirteen thousand francs (113,000 fr., 4,620*l.*) will be taken in the estimates of the Ministry of Public Instruction, Worship, and the Fine Arts, for the year 1879, to appear in the first section (Public Instruction), in addition to chapter XIV., Astronomical Establishments.

Article IV.

A vote for two hundred and thirty-two thousand francs (232,000 fr., 9,280*l.*) will be taken in the estimates of the Ministry of Public Works for the year 1879, to appear in a new chapter of the 2nd section of the Budget No. 60, and entitled, "Works relating to the Establishment of the Observatory of Astronomical Physics of Meudon."

Article V.

The expenditure authorised by the preceding Articles III. and IV. shall be provided for by the general resources of the Budget for 1879.

the year 1870. I will not enter specially into the advantages of such charts but mention one only. It is very important when the protuberances in the region are further north or south if there is simultaneously a spot on the extreme outer edge. I have given many cases in which the protuberances had a contrary direction or appeared in the region as divergent clusters. This had not been noticed.

The compilation of the materials of observations in the manner indicated I would entrust to the Committee, but nothing further. Their use and manipulation must be left to individuals, on their own responsibility, and not be invested with the authority of the Committee.

The compilation of the sun-spot regions (directly observed with a telescope or taken by photography) I would *not* entrust to the Committee nor yet the computation of the regions. As to the "rotation elements" no agreement need be expected in the near future; their computation, also, must be left to individual observers. For observation no definite *principia* are followed. Faye laid down in the Compte Rendu that the measurement should be from the Dawes dark point in the nucleus, but Faye himself is not an observer, and consequently cannot know that his proposal is not practicable. If a large spot has several *nuclei* one observer measures the centre of the whole spot while another seeks out the largest nucleus, and finds nothing to refer the variations. Such published observations as these I cannot use for my researches. One must have regard for the variations, especially if one wishes to contemplate a particular spot as identical with a spot of the following rotation period. The centre of a largely affected appearance in the first rotation period is *not* identical with the centre of a smaller spot of the second period, and if one considers them as identical there will at once be a too deep parallax. My observations which I am about to publish contain a confirmation of my former deep parallax (including refraction), viz., the sectional. Accordingly a correction belongs to the calculated regions, and is necessary.

For the prosecution of researches for the exact determination of Ω and i, I would observe that it cannot be expected that out of the discussion of a very large number of spots the right elements can be found, but one has to pick out those which are preferable. A good result would follow if it were assumed that the difference in the variation of longitude arises, if one takes a nearly similar number of spots in both hemispheres. My researches (which are not published) show that the northern hemisphere in respect to

As a more convenient illustration of the progress of the change in the solar activity as regards the formation of spots, we reproduce the figures in the following table, for the year 1871 as well as for those of 1869 and 1870, for in our last year's report we did not mark all the periods during which views could not be obtained with special (Roman) figures

In this table we have adopted January 3·56 as the commencement of the 1869 period.

1869.				1870				1871.			
Period of Revolution	No of Views taken	Total Area of Spots each Day		Period of Revolution	No of Views taken	Total Area of Spots each Day		Period of Revolution.	No, of Views taken	Total Area of Spots each Day	
		N	S.			N	S,			N	S
I.	0	—	—	XIV	0	—	—	XXVIII.	6	170	299
II.	1	31	33	XV.	0	—	—	XXIX	1	86	1,294
III.	0	—	—	XVI.	8	494	723	XXX.	13	347	838
IV.	10	25	262	XVII	11	1,156	575	XXXI.	3	339	1,176
V.	11	207	662	XVIII.	12	262	450	XXXII	4	338	625
VI.	8	307	346	XIX	3	355	1,547	XXXIII.	7	382	68
VII.	9	109	289	XX.	14	584	103	XXXIV.	10	307	527
VIII.	9	37	155	XXI.	15	446	91	XXXV	10	368	298
IX.	8	233	291	XXII.	11	586	277	XXXVI	9	674	330
X	7	370	483	XXIII	10	776	424	XXXVII	5	219	434
XI.	5	241	13	XXIV	8	1,938	292	XXXVIII	5	119	165
XII	2	162	201	XXV.	0	—	—	XXXIX	3	199	491
XIII.	2	381	213	XXVI.	0	—	—	XL	1	546	131
				XXVII.	1	325	792	XLI	0	—	—

The conclusion at which we arrived last year from the above data in respect to the successive variations of the solar energy in the two hemispheres, namely, that during the period of our observations (1869 and 1870) the increase or diminution of the activity producing the spots generally showed itself first in the south, and then passed to the north, is evidently applicable only until the period XXXI or XXXII., in the month of April 1871, in this month the spots reached their second maximum, (the first was in September 1870), after which, apparently, the variations of energy began in the northern hemisphere Owing, however, to the insufficiency of our data, we are not in a position to come to a definite conclusion

We have already mentioned that September 1870 was the epoch of maximum of spots. Commonly about the time of maximum the curve which marks the change in the total areas of the spots rapidly rises, reaches its highest point, and bending at a sharp angle falls as rapidly. Taking the diagram attached to the Kew *Report* of 1870. "the positions and areas of the spots observed at Kew during "the years 1864, 1865, and 1866, also the spotted area of the sun's "visible disc from the commencement of 1832 up to May 1868," and *combining with this diagram* the *curve* representing the result of our own three years' observations, we can show how this *curve* varied about the periods of the maximum in January 1837, October 1847, and September 1870 The abscissæ of our supplementary curve are exactly those of the Kew diagram, *i.e.*, each horizontal side of the

Registered No. 30,205, 1885, from Professor Riccò, of Reale Observatorio, Di. Palermo. Letter dated 8th June 1885. "Expresses his desire to attend, and has addressed " an application on the subject to the Italian Government."

Registered No. 31,561, 1885.

Princeton, New Jersey, U.S.A.,
10th June 1885.

SIR,

I have duly received yours of May 19th, and sincerely regret that it will not be in my power to attend the proposed meeting of men of science engaged in solar research. I heartily approve the plan, and am greatly honoured by the invitation to be present, but family considerations make it impossible for me to go abroad this summer.

As regards the scheme of Dr. Janssen, while I have not time as yet to examine and form an opinion upon every point involved, I think it on the whole a very admirable one; one which would secure a rapid increase of our knowledge.

I should be happy to co-operate with the proposed "*Comité international des études solaires*" to the extent of my ability.

The only difficulty I feel relates to the pecuniary resources. I could not promise any considerable contribution from my *private* means, and at present I have no other funds in my control. Were such a Committee formed, however, I should have some hopes of being able to obtain a grant from the University to supply my quota; but I am not in a position to make absolute promises.

I am, Sir,
Very respectfully,
Your obedient servant,
(Signed) C. A. YOUNG,
Professor of Astronomy.

Frank R. Fowke, Esq.,
Secretary to Solar Physics Committee.

Registered No. 31,699, 1885.

Harvard College Observatory,
Cambridge, U.S.,
11th June 1885.

SIR,

Your letter of May 19th has been duly received. Other occupations will deprive me of the pleasure of attend-

APPENDIX VI.

Circular Letter to Directors of Solar Observatories on International Co-operation.

Sir,

I have already had the honour of communicating with you on the subject of international co-operation in the making and publication of Solar Observations.

In my last letter I stated that it had been necessary to abandon the proposed conference on account of the difficulty of fixing a time which would be generally convenient. The object which the Solar Physics Committee has in view, at the present time, is to endeavour to see therefore whether the desired co-operation can be brought about by means of correspondence.

The labours of the Committee both before and since the date of my last letter have resulted in arrangements which may be expected to secure a solar photograph on a scale of at least 8 inches to the sun's diameter for every day in the year. These photographs are taken at Greenwich, in India, Mauritius, and Australia.

Arrangements have also been made by which the reductions of these photographs are undertaken by the Astronomer Royal; these reductions include heliographic latitudes, longitudes, and areas of spots, and also positions and areas of faculæ, the areas being stated in millionths of the sun's visible hemisphere.

For these reductions, the solar rotation of 25·38 mean solar days is taken, and the assumed prime meridian is that adopted by Carrington, so that the reductions made at the present time are based on the same data as those assumed in Carrington's series.

The Solar Physics Committee are willing to take such steps as will enable them to place these reductions in the hands of all solar observers at the earliest possible moment; and if adequate co-operation can be secured, they believe they will also be able to supply copies of the daily photographs.

The Committee believe that if this information could be placed in the hands of observers at an early period after the day of observation, much time now spent in determining positions of spots whether from drawings or photographs might be saved for other inquiries.

on the issue of such a bulletin, I am directed to observe that if there is any fund at your disposal from which a proportional part of such expense might be contributed, or if you were able to subscribe for a certain number of copies of the bulletin, at a price to be fixed hereafter, it would assist materially in giving practical effect to the proposed scheme.

APPENDIX E.

From Major-General J. F. WALKER, C B , R E., Surveyor-General of India, to the SECRETARY, Science and Art Department, South Kensington, London, S.W.

Government of India,
Surveyor-General's Field Office,
Mussoorie, dated 4th July 1879.

SIR,

IN reply to your letter of the 13th May I have to state that the possibility of having actinometric observations made in India, and of obtaining interesting and valuable results from them, has already been established by the operations at Dehra Dún and Mussoorie, in October and November 1869, of which an account will be found in a letter from J. B. N Hennessey, Esq , Deputy Superintendent of the Great Trigonometrical Survey, at pages 225 to 231 of the Proceedings of the Royal Society, No. 125, 1870.

2 I gather, however, from the papers accompanying your letter that the object now in view is to obtain continuous actinometrical observations for as long a period as possible, for which purpose a site well elevated above the lower strata of the atmosphere, and situated beyond the influence of the Indian monsoons, in some fairly civilized locality where the necessaries of life are to be obtained without much difficulty all the year round, is necessary.

3. Such a site, I believe, is to be found in Leh, as already suggested in the Report accompanying your letter. Dr Cayley, who resided there during the greater portion of the year (though not during the winter) for four years, and of whom I made inquiries on the subject when I received your letter, replied as follows:—

"I believe, from much experience of the climate, that few better places in the world could be found than Leh for any sun observation. The number of cloudy days in the year is very small. One may say that from early April to October there are almost none. The air is perfectly dry and free from moisture, and without vapour of any kind. There is not on an average above 2″ of rain. During the five winter months there is more cloud and some snow, but still comparatively little, nothing like the more southern Himalayas, and there is far more of clear than cloudy weather.

"As to dust there is often a good deal of dust and sand blowing up *in the valley of the Indus below Leh* in the windy part of the afternoon, but it is very partial and never obscures the sky, and at Leh itself, which is between four and five miles up a side valley, and is surrounded by cultivated and irrigated fields, there is no dust at all; the air is always perfectly transparent, so that the most distant mountain peaks are as sharply defined as if they were close at hand. In the wide plain of Chanthang beyond Changchenmo you get driving storms of dust and sand, and often saline matter, pretty nearly every afternoon, and I suppose in Yarkand in summer there is a constant atmosphere of dust; but in Ladak there is nothing of this kind, and I believe Leh would prove a most perfect site for taking actinometric observations"

4. Leh is 11,500 feet high above the sea level; it is situated in latitude 34.10, where the meridian altitude of the sun ranges from 32° to 80°. The fixed population is said to range from 500 to 1,000 souls. A European gentleman, Mr. Johnson, Wazir to the Moharajah of Kashmir, resides there all the year round, and the Agent for

temperatures are in question, whilst on the descending side of the curve the spectra will depend upon successive chemical combinations rendered possible by a gradual reduction of temperature in a gaseous mass.

The spectroscopic observations of the IIa. stars have hitherto been made on the supposition that all of them were cooling bodies, so that no effort has been made to establish the necessary criteria. The spectroscopic criteria which will enable observers to assign any particular Class IIa. stars to either Group III. or Group V., as the case may be, of the new classification have recently been determined by work in the observatory.

(5.) *Tests.*

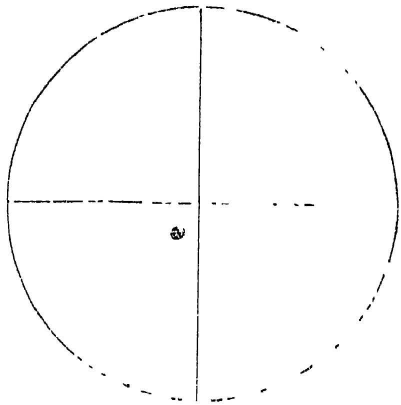
As a test of the truth of the hypothesis, Mr. Lockyer shows how it bears the strain put upon it when it is used to indicate how the groups should be still further divided, and what specific differences may be expected. Thus, the first species of Group I. will include the least condensed swarms, and succeeding species will include the more condensed ones. The last species of all will consist of the hottest of the "stars" with bright lines, like γ Cassiopeiæ. In passing through this series, the spectroscopic differences observed between the different species are just what would be expected on the supposition that meteorites at gradually increasing temperatures are in question, and the general hypothesis is thus greatly strengthened.

It is also shown that if the next group (Group II.) be discussed in a similar manner, the same conclusion is arrived at. The actual spectroscopic differences observed are exactly what they would be in a condensing swarm of meteorites with a gradually increasing temperature. The 297 stars of this group which have been observed by Duner have been divided by Mr. Lockyer into 15 well defined species, the first beginning where the last of the preceding groups leave off.

The subject of variability, as far as it is associated with the stars which Mr. Lockyer has shown to be uncondensed meteor-swarms, was also considered at some length in the Bakerian Lecture. Mr. Lockyer's explanation of variability is closely allied to that of Newton, who ascribed the increase of brightness to the appulse of comets.

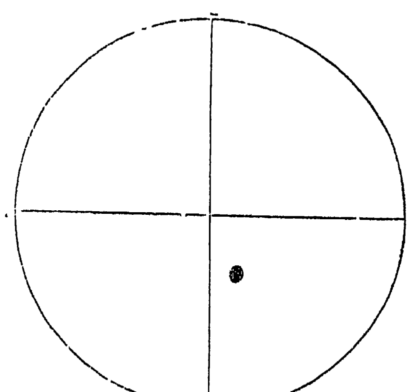
According to Mr. Lockyer, however, the variability in this class is produced in the simplest case by the revolution of a

1st September —The nucleus had changed to the shape of the figure 3 and was much darker; the little spot to the east had broken



up into three smaller ones Several more lines were affected, but between b and F a darkening of the lines was observed but no widening.

2nd September.—The nucleus had become pear-shaped and was very dark; the three small spots to the east had also disappeared. The atmosphere was very clear, and I could easily detect in the spectrum the absorption due to the pores. I noticed to-day a great number of lines between b and F widened (see the subjoined list)



3rd September.—I was again able to observe the spot under very favourable conditions. It was still pear-shaped, but the narrow end seemed as though it was being forced outwards. The absorption was much increased and a greater number of lines were widened, as the following table shows.

bodies of the universe. As far as can at present be stated, the sun belongs to one of the later stages of Group V., that is to say, it has already passed through the nebulous stage, and the stages represented by stars like α Orionis, α Tauri, and α Lyræ, and has still to pass through the stage represented by stars like 152 Selij. before it finally becomes a dark planetary body. There is evidence that the time taken for a nebulous swarm to reach the hottest stage is less than that taken for the subsequent cooling to the planetary stage, so that although the sun has already cooled very considerably, it is probable that it is still only about half way in point of time on its journey from the nebulous to the planetary stage.

The experiments on the spectra of meteorites are especially interesting in connexion with the probable meteoritic nature of the sun's atmosphere, and the theory which ascribes sun-spots to falls of this meteoric matter into the photosphere.

The solar spectrum can be very nearly reproduced by taking the spectrum of a mixture of stony meteorites between the iron meteoric poles of an electric arc. Photographic comparisons of this kind, on a large scale, have been taken for the region of the spectrum lying between K. and D.

The absence of carbon and oxygen from the sun (or their presence in very small quantities) and the presence of hydrogen also receive explanation by the meteoric hypothesis. It is known that the vapours in the heads of comets are driven outwards from the sun by some repulsive force. If this force is so intense at cometary distances, it may fairly be expected that it will also exist at the sun's surface, and consequently the permanent gases will be repelled. In this way the absence of oxygen and compounds of carbon is accounted for. Hydrogen is also repelled in a similar manner, but as quickly as it is driven away more is formed by local dissociation.

Another reason for the absence of carbon is, that if it by any means could descend as low as the photosphere, it would be immediately dissociated.

Spot No. 1. 1879 (August 30th—Sept 3rd).

In Table I. is given a list, for each day that observations were made, of the lines affected in this spot; and likewise a list of lines affected in a spot examined at Greenwich in October 1877, which the Astronomer Royal has kindly supplied to the Committee.

The second order spectrum of a grating having 17,280 lines to the inch was used for these observations

In Table II. a reduction of these observations has been made, and tables are given showing the effects of the spot upon metallic lines The metals included in this reduction were chosen either because some of their lines were seen widened in the spots, or else because they have lines coincident with those of another metal within the region under discussion, viz, from b to F.

Metals having lines with reading in Thalén's list identical with those of the metal under consideration are entered under "Coincidences," whilst those lines which are basic according to Ångstrom's Map will be found in the last column of the table under Coincident Metals in Ångstrom's Map.

Table III. shows how Thalén's basic lines were affected in this spot

Table IV. is a summary of Table II The total number of unaffected metallic lines, added to those seen in spots and storms and diminished by those common to both, gives the total number of metallic lines

The chief difference between this spot and that of October 26th 1877 is the great increase in the number of lines widened or otherwise affected Thus it will be found that in the year 1877 only 21 lines were widened in the region between b and F, whilst in this spot no less than 140 lines are so affected, but strange to say five of the lines widened in 1877 are not affected in this spot.

Fourteen of the 21 lines seen in 1877 have corresponding readings in metallic spectra, and such also is the case with no less than 99 of the lines seen this year

It will be found on examining the table of basic lines that of the 7 basic iron lines all were widened this year, whilst in the year of minimum sun spots three only were affected. Again this year two out of the four basic titanium lines are recorded as having been widened, whilst in the year 1877 only one basic titanium line was affected.

List of Lines seen widened in the Region between b and F (wave lengths 5183·0 to 4860·0).

Note.—The metals entered in italics are taken from Ångstrom's map, those in roman from Thalen's table.
"w" indicates the amount of widening, a single "w" being the smallest widening.
"d" ,, ,, darkening, ,, "d" ,, darkening.
"f. s. l." means faint solar line "l" = line ,, "n" or "nr" = near

Greenwich. 31st Oct 1877.	Greenwich 3rd Nov 1877	Kensington 30th Aug 1879	Kensington 1st Sept. 1879	Kensington 2nd Sept 1879	Kensington 3rd Sept 1879.	Metals.
b_1 5183·0	5183·0	5183·0 w	5183·0 w	5183·0 w	5183·0 w	Mg
					5176·2 w	
		f s l less refrangible than b_2		ib	ib.	
b_2 5172·0	5172·0	5172·0 w	5172·0 w	5172·0 w	5172·0 w	Mg Te
				5171·1 w	5171·1 w	Fe
b_3 5168·3	5168·3	5168·3 w	5168·3 w	5168·3 w	5168·3 w	Fe Ni
b_4 5166·7	5166·7	5166·7 w	5166·7 w	5166·7 w	5166·7 w	Fe Mg.
					5165·8	*Fe*
					5164·5	*Fe.*
					f s l. less refrangible than 5161·5 ww	
				5161·5 w	5161·5 w	Fe.
					f s l. less refrangible than 5158·5 ww	
				5158·5 w	5158·5 ww	*Fe.* Zn.
					f s. l. near 5156·0 ww	
				5153·2 w	5153·2 w	Ti
				5152·5 w	5152·5 w	Tl Na
				5151·2 w	5151·2 ww	Ti *Fe.*
				f s l. nr. 5150·0 www		
				5150·0 d		*Fe.*
					f s l nr 5140·9 www	
				5147·2 w	5147·2 ww	*Fe.*
				5142·2 w	5142·2 ww	
				5141·9 w		Ni. *Fe.*
				f s. l nr 5140·0 www		
					5138·6 ww	Fe
					l nr 5138·0 ww	
					5136·8 w	Ni. *Fe.*
					l nr 5136·0 ww	
					5133·0 d	Te. *Fe.*
					5132·0 ww	
	5114·9					
	5109·8					
	5108·8					
					5107·0 w	*Fe.*
					5102·1 www	
	5099·2					
	5098·5			5098·5 w		Ni.
	5098·1			5098·1 w	5098·1 www	*Fe.*
					bright gap nr. 5095·0 5085·0	
				5083·5 w	,, ,, 5083·5 w	
				5082·2 w	5082·2 w	*Fe.*
				5081·8 w		
				5080·6 w		Ni.
				5078·8 ww		*Fe.*
				5077·9 ww	5077·9 www	*Fe.*
	5075·8				5075·8 w	*Fe*
					5074·0 w	Zn *Fe.*
				5071·8 w	5071·8 w	Ti *Fe.*
					5068·1 w	Wo. *Fe.*
					5066·3 w	*Fe.*
					5064·4 ww	Fe Ti.
				5051·0 w	5051·0 w	Fe.
				5049·4 w	5049·4 w	Fe.
				5048·0 w	5048·0 w	Zn.

Greenwich. 31st Oct 1877	Greenwich. 3rd Nov 1877	Kensington 30th Aug 1879.	Kensington 1st Sept 1879.	Kensington. 2nd Sept 1879.	Kensington 3rd Sept. 1879.	Metals
				5047 8 w	5047·8 w	*Fe.*
	5044 5					
	5043 3				5043·3 ww	Ti *Fe.*
	5041 2			5041 2 d	5041 2 w	Fe Ca.
	5040 2			5040 2 d	5040 2 w	Fe.
					5037·8 w	*Ti.*
	5035 8				5035 8 ww	*Ti.*
	5035 3				5035 3 ww	
	5034 7				5034·7 w	Ni.
					5027 2 w	*Fe.*
					5026·2 w	*Fe.*
					5025 5 w	
					5021·7 w	
					5021 4 w	*Fe*
					5019 3 w	Ti. *Fe.*
					5017 5 d	
					5016 5 w	Ni.
					Bright line nr 5015 0	
					5014 2 w	*Fe.*
					5013·3 w	Ti.
					5011·4 w	Cu *Fe.*
				5006 6 w	5006 6 w	Ti. *Fe.*
				5005 2 w	5005·2 ww	*Fe*
				5004·9 w		*Fe*
					5003 1 w	*Fe.*
					5002·0 w	Fe
					5001 0 w	Ti.
					4999·9 w	
					4998 8 w	Ti.
					4997 4 w	
					4995 8 w	
					4993·3 w	Fe.
					4990 3 w	Fe Ti.
					4988 3 w	Fe Ti. *Na*
	4984·8				4984·8 w }	*Fe.*
				4984 7 w	4984 7 w }	
				4983 5 w	4983·5 w }	Ni.
					4983·3 w	Ni. *Na.*
					4982 5 w	Na.
					4981·9 w	*Na.*
					4981 8 w	
	4981 0			4981 0 w	4981 0 w	Ti Wo.
				4979·6 w	4979·6 w	Ni.
				4977 8 w	4977 8 w	Ti.
					4975 9 ww	
					4975·2 ww	Ti.
					4970 0 ww	Bi Ce.
					4969·4 ww	*Fe.*
					4969 0 ww	*Fe.*
					4967·7 ww	Ti. *Fe.*
					4967·3 ww	*Fe.*
					4964 5 w	Ti.
					f. s. l. nr 4959 0 w	
					4956·7 d	Fe.
				4954 2 w	4954 2 w	*Fe.*
				4952 2 w	4952 2 w	*Fe.*
				4949·3 w	4949 3 w	*Fe.*
				4945 8 w	4945·8 ww	*Fe.*
					4945 2 ww	
					4944 0 w	
				4941·4 w	4941 4 d	*Fe.*
				4938 8 w	4938·8 ww	*Fe.*
				4938 4 w	4938·4 ww	*Fe.*
				4938·0 w	4938·0 ww	
				4933·4 w		Ba.
				4927·0 w		
				4924 4 w		
				4923 1 w		Fe.
				4921·2 w		
				4919·8 ww	4919·8 d	Fe.
				4918 2 w	4918·2 d	Fe.
				Faint lines more refrangible than 4918 0		

Greenwich 30th Oct. 1877.	Greenwich 3rd Nov 1877	Kensington 30th Aug 1879	Kensington 1st Sept 1879.	Kensington 2nd Sept 1879	Kensington 3rd Sept 1879	Metals
				4902 5 w	4902 5 d	*Fe*
				4890 7 w	4890 7 d	Fe.
				4890 0 w	4890 0 d	*Fe.*
				4888 3 w	4888 3 w	
				4888 0 w	4888 0 w	*Fe.*
					4886 4 w	*Fe*
					4885 9 w	*Fe.*
					4884 2 w	*Ti*
					4882 7 w	
				4880 9 w	4880 9 w	*Fe*
				4877·4 w w	4877 4 w	Ca. Fe
					4875 2 w	
				4871 3 w	4871 3 w	Fe.
				4870·5 w	4870 5 w	Fe
					4867 5 ww	Ti Mo.
					4863 5 ww	Th
F 4860·7	4860 7			4860·5 w	4860·5 d	H.

Sodium.

Thalen.			Spots.		Storms (Young)		Coincident Metals in Angstrom's Map
Wave Lengths.	Intensities.	Coincidences.	1877 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness	
5151 8	3		.		3	3	
5152 5	3	Ti (2)	.	w	3	1	*Cr*
4983 3	Map	.	.	w	.		*Fe*
4982 5	4	.	.	w	.	.	
4981·9	Map		.	w	.	.	*Fe.*

Magnesium.

b_1 5183 0	1	.	w	w	50	30	
b_2 5172·0	1	Te (5)	w	w	50	35	
b_4 5166 7	1	Fe (2)	w	w	30	20	

Zinc.

5158·5	4	..	..	w w		..	
5121 0	4	Erb + Y (2)	.	..	1	1	
5074·0	4	..	.	w	..	..	Fe
5018·0	4	..	.	w	.	..	*Fe*
4971·0	4	..	.	..	.	..	
4923·8	1	.	.		.	.	
4911·2	1	..	.	.	3	2	
4878·0	5	.	..	.	.	..	

Cadmium.

Thalén.			Spots		Storms (Young).		Coincident Metals in Ångstrom's Map.
Wave Lengths.	Intensities	Coincidences.	1877 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness	
5153·0	4	..	.	.	.		
5085·0	1	Ti (1)		.	..	..	

Barium.

4933·4	1	.	..	w	30	8	
4899·3	2	Ti (2)	.	..	30	6	

Calcium.

5041·2	2	Fe (3)	w	d	2	2	
4877·4	3	Fe (3)	..	ww	..	..	

Nickel.

5175·5	Map	.	.	..	..	..	
[b]5168·3	5	Fe (3)	w	w	40	30	
5155·1	5		..	.	.	..	
5145·7	5	.	..	.	..	.	*Fe.*
5142·0	5	..	..	w	..	..	*Fe.*
5136·8	5	..	.	w	..	..	*Fe.*
5114·9	5	..	w	.	1	1	
5099·7	5	..	..		..	..	
5098·5	5	..	w	w	.	..	
5080·6	5	.		w	..	..	
5079·7	5	..	.		..	..	
5034·6	3	..	w	w	..	..	
5016·5	3	..	..	w	..	.	*Fe.*
4983·3	5	..	..	w	.	..	
4979·6	5	..	..	w	..	.	
4935·1	3	..	..	..	..	..	
4917·6	3	..	..	..	..	..	
4903·9	3	Ti (4)	..	..	..	..	
4872·9	1	..	..	.	..	..	
4865·3	1	..	..	..	..	..	

Iron.

5168·3	3	Ni (5)	w	w	40	30	
5166·7	2	Mg (1)	w	w	30	20	
5165·8	Map	..	..	w	..	..	
5164·9	,,	..	..	w	..	..	
5161·6	4	..	..	w	..	..	
5158·6	Map	..	..	ww	..	..	
5151·2	,,	..	.	w	..	.	
5150·0	,,	..	..	d	2	2	
5147·2	,,	..	..	ww	..	..	*Ni.*
5145·7	,,	..	..	..	..	..	*Ni.*
5141·9	,,	..	..	w	..	..	
5138·6	2	..	..	ww	..	..	

Thalen.			Spots.		Storms (Young).		Coincident Metals in Ångström's Map.
Wave Lengths	Intensities	Coincidences	1877. 26 Oct. 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness	
5136·8	Map	.	.	w	.	..	
5133·0	”	.	..	w	1	1	
5130·9	”	..	..	..	1	1	
5126·7	”	..	.	..	1	1	
5124·3	”	..	..	..	1	1	
5123·2	”	..	..	..	1	1	
5121·0	”	..	..	..	1	1	
5109·9	”	..	w	.	..	.	
5107·0	3	..	..	w	1	1	
5098·1	Map	.	w	www	1	1	
5096·3	”	..	..	..	1	1	
5090·2	”	..	..	..	..	..	
5082·2	”		..	w	..	.	
5078·8	”	..	..	ww		.	
5077·9	”	..		www	1	2	
5075·8	”		w	w	.	.	
5074·0	”	..		w	..	..	
5071·8	”	.	.	w	.	..	
5068·1	”	.	..	w	..	..	
5066·3	”	..	..	w	.		
5064·4	4	Ti (1)	..	ww		.	
5059·8	Map	..		.	..	..	
5051·0	2	..	..	w	..	..	
5049·1	2		.	w	..	..	
5047·8	Map	.	..	w	2	2	
5043·3	”	..	w	ww	..	.	
5041·2	3	Ca (2)	w	w	2	2	
5040·1	3	.	w	w	2	2	
5038·2	Map	..	..	..	.	..	
5027·2	”	..	.	w	..	..	
5025·2	”	..	.	w	..	..	
5021·4	”	..	..	w	.	.	Ti.
5019·3	”	..		w	..	..	
5014·2	”	..	.	w	.	..	
5011·4	”	..	..	w	..	.	
5006·6	”	..	..	w	..	.	
5005·2	4	..		ww	..	..	
5004·9	Map	.		w	.	..	
5003·1	”	..		w	..	.	
5002·0	5		..	w	2	1	
4993·3	5			w	..	..	
4990·3	4	Ti (1)	..	w		.	
4988·3	5	Ti (3)	..	w	..	..	
4984·7	Map	..	..	w		..	
4983·5	”	..	..				
4982·5	”	.	..	w	.	..	
4981·9	”	..	..	w		..	
4977·8	”	..	..	w	..	.	
4972·2	”	..	..	.	.	..	
4969·4	”	..	..	ww	..	.	
4969·0	”	..	.	ww	.	..	
4967·7	”	..	..	ww	.	.	
4967·3	”	..	.	ww	..	..	
4965·2	”	..	..	..	..	..	
4961·8	”	..	..	d	1	2	
4956·1	1	.	..	w	..	.	
4954·2	Map	..	..	w	..	.	
4952·2	”	..	..	w	..	..	
4949·3	”	..	..	ww	.	..	
4945·8	”	.	..	w	..	.	
4944·4	”	..		ww	..	..	
4938·8	”	..	.	ww	..	.	
4938·4	”	..	..	..	..	..	
4932·6	”	..	.	..	..	.	
4929·4	”	..	..	..	..	..	
4928·0	”	..	..	w	40	12	
4923·1	”	..	..	ww	..	..	
4919·8	”	..	..	w	20	3	
4918·2	”	..	..	..	..	..	
4909·6	Map	..	..	..	..	..	
4907·0	”	..	.				

Thalén			Spots		Storms (Young)		Coincident Metals in Ångstrom's Map
Wave Lengths	Intensities	Coinci-dences	1877 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency.	Brightness	
1902·5	Map	· ·		w		· ·	
4890 4	1	· ·		w		·	
4890 0	Map			w		· ·	
4888·0	,	·		w			
4886 4	,	·		w			
4885·9	"	·	·	w			
4884·2	"			w	·	·	*Ti.*
4880 9	"			w	·		
4877 4	3	Ca (3)		ww			
4875 2	Map	· ·		w			
4871 3	2	· ·		w			
4870·5	2			w			
4863·6	Map			w w			

TITANIUM.

5173 0	2	· ·	·				
5153·2	3	·	· ·	w			
5151 2	2	·		·	· ·		
5147 0	3			·	·	·	*Fe.*
5144 5	2			·		· ·	
5128 6	1	·			1	1	
5126 6	4		·		1	1	*Fe.*
5119 9	1	· ·	· ·	· ·	1	1	
5113 0	2						
5108 6	4			·	2	2	
5102·4	4						
5086 5	2				·	·	
5076 5	4					· ·	
5071 8	4			w	·	·	
5065 5	4			·		· ·	*Fe.*
5064·1	1	Fe (1)		w		·	
5061 3	3			·		·	
5052 3	3			·	·		
5043 1	3	·	w	w			
5039 2	2	·					
5038 7	Map				·	· ·	
5038 0	2			·		·	
5037 8	Map			w		· ·	
5035 8	"	·	w	w	·	·	
5035 6	1	·	·	· ·	·	·	
5035 2	Map		w	w	·	·	
5024 8	3		· ·	·	·		
5023 8	3			·	·		
5021 2	3				·	·	
5019 4	2	· ·		· ·			
5015·3	2	·	· ·		30	10	*Fe.*
5013 3	1			w		·	
5012 2	4		·	· ·	· ·		
5006 6	1	·	· ·	w	· ·	· ·	
5001 0	4	· ·		w		·	*Fe.*
4998 8	1			w			
4990 3	1	Fe (4)	·	w	·	·	
4988 3	3	Fe (5)	· ·	w	·	·	
4981 0	1	Wo (1)	w	w	· ·	· ·	
4977·8	3		·	w	·	· ·	
4975·2	4	·	·	w		· ·	*Fe.*
4972 2	5		·	·	· ·		
4967 7	5		·	w	·	·	
4964·5	5	· ·	·	w		·	*Fe.*
4947 0	5	·	·	·	·	·	
4937 2	2	· ·			·		
1927·5	2	· ·	· ·	· ·	· ·	· ·	
4925·0	4	·	· ·	·	· ·	· ·	
4920·8	8	· ·	· ·	· ·	· ·	· ·	

Thalén			Spots.		Storms (Young)		Coincident Metals in Ångstrom's Map
Wave Lengths	Intensities	Coincidences.	1877. 26 Oct 7 Nov	1879 30 Aug 3 Sept	Frequency	Brightness.	
4919·0	3	..	..	..	..	..	
4913·2	3	..	..	.	..	..	
4911·3	3	.	..	..	..	..	
4903·9	4	Ni (3)	..	..	..	..	
4899·3	2	Ba (2)	..	..	30	6	
4884·5	1	..	..	..	..	..	*Fe.*
4873·0	4		..	..		..	
4869·0	2	.	.	..	.	..	
4867·5	2	Mo (4)	..	w	..	..	*Co.*

Molybdenum.

4979·0	5		..	.	..	.	
4867·5	1	Ti (3)	.	w		..	*Co.*

Tungsten.

5070·5	3	.	.		.	.	
5068·0	3			w	.		*Fe.*
5053·0	1	.	.	..		.	
5014·1	3		..	..	.	..	
5007·0	3	Tl (3)	.		.	.	
4981·0	1	Ti (1)	..	w			
4887·5	2	.		..	..	..	

Thorium.

4919·0	3	.	..	..	.	.	
4863·5	3	.	..	ww	..	..	*Fe.*

Vanadium.

4881·0	3	..		..	..	..	
4874·5	3	Pd (3)	.	.	..	..	
4864·0	1	.	..	.	.	..	

Antimony.

5177·0	3	Di+La	..	..	..	..	
5141·0	1	..	..	..	..	..	
5112·5	4	.	..	.	..	.	
5036·0	5	..	..	..	..	..	
4948·5	2	..	..	..	..	.	
4877·5	3	..	..	..	..		

Bismuth.

Thalen			Spots.		Storms (Young).		Coincident Metals in Ångström's Map.
Wave Lengths	Intensities	Coincidences	1877. 26 Oct. 7 Nov.	1879 30 Aug 3 Sept	Frequency	Brightness.	
5143·5	1	.	.	.	.	..	
5123·5	1	.	..	.	.	..	
5090·5	5	.	.	.	..	..	
5077·5	4	..	..	.	.	.	
4993·0	1	.	.		.	.	
4970·0	5	Ce (5)	w	.	..	..	
4905·0	4	..	.	..	.	..	

Copper.

5152·6	1	..	.	w	.	.	*Ni.*
5104·9	1			.			*Fe.*
5011·4	4	.		w		..	
4955·5	3	..		..		.	
4932·5	3		.	..	.	.	
4911·5	3	.	.	..	.	.	

Thallium.

5152·5	2	Na (3)	..	w	3	1	*Cu.*
5085·0	4			..	..	.	
5078·5	3	Cd (1)	.	..		..	
5053·0	3	Wo (1)	..	.	..	..	
4981·5	3	Erb + Y (4)	..	..	..	..	
4945·5	4	..	.	.	..	..	
4892·0	4	..	.	..	..	.	

Erbium and Yttrium.

5134·5	5	..	..	..	..	..	*Fe.*
5126·5	4	.	..	..	..	..	
5121·0	2	Zn (1)	..	..	1	1	
5117·5	3	..	..	..	.	..	
5087·0	1	..	.	.	1	1	
4981·5	4	Tl (3)	..	..	..	..	
4971·0	4	..	..	..	..	.	
4935·0	4	.	..	.	..	..	
4900·0	1	Di + La (1)	..	..	..	..	
4882·5	1	Di + La (1)	..	..	..	..	

Cerium.

5161·0	5	..	..	..	..	..	
5079·0	3	..	..	..	..	..	
5072·0	4	..	..	..	..	..	
4970·0	5	Bi (5)	ww	..	..	..	

Palladium.

5163·0	1	..	..	..	..	..	
5116·5	2	..	..	..	..	..	
5110·0	2		.	.	..	..	
4874·5	3	Va (3)	..	..	..	..	

Didymium and Lanthanum.

Wave Lengths.	Thalén. Intensities	Thalén. Coincidences.	Spots. 1877 26 Oct 7 Nov	Spots. 1879 30 Aug 3 Sept	Storms (Young). Frequency	Storms (Young). Brightness	Coincident Metals in Angstrom's Map
5182·0	1	.	.	.	.	.	
5177·0	4	Sb (3)	..		.		
5157·0	4	..	.	..			
5144·0	4	.		..	.		
5130·5	3	.					
5122·5	3	.	.		.	.	
5114·0	3		.	.	.	.	
5055·5	5	.	..	..			
4999·5	4	.	.	.	..	.	
4968·0	4	.		.	.	.	
4950·0	4	.	.	.	.	.	
4934·0	4		..			.	
4920·0	1		.			.	
4900·0	1	Erb+Y (1)	.	.	.	..	
4882·5	1	Erb+Y (1)	.	..		..	

Tellurium.

b_2 5172·0	5	Mg (1)	w	w	50	35	
5152·0	3	.	..	.	..		
5133·0	5	.		w	1	1	
5104·5	3		.		.	..	
5037·0	4	.	.	..			
4895·0	5	.		.	..		
4866·5	4	..				.	

Table III, showing how Thalén's Basic Lines were affected in the Spots of August 26th to September 3rd, 1879, and October 26th to November 7th, 1877.

Wave Length	Thalén. Common to	Thalén. Intensity.	Spots. Widened 1877.	Spots. Widened 1879	Storms (Young). Frequency.	Storms (Young). Brightness
5168·3 b_3	Fe Ni	3 5	w	w	40	30
5166·7 b_4	Fe Mg	2 1	w	w	30	20
5064·4	Fe Ti	4 1		w		.
4990·3	Fe Ti	4 1		w	.	.
4988·3	Fe Ti	5 3	.	w		
5041·2	Fe Ca	3 2	w	w	2	2
4877·4	Fe Ca	3 3	..	w	.	.
4981·0	Ti Wo	1 4	w	w	..	.
4867·5	Ti Mo	2 4		w	.	..
5152·5	Na Tl	3 2	.	w	3	1
5172·0 b_2	Mg Te	1 5	w	w	50	35
4970·0	Bi Ce	5 5		w	.	
4903·9	Ti Ni	4 3	..	..		.
4899·3	Ti Ba	2 2	..	.	30	6
5121·0	Erb+Y Zn	2 4	.	.	1	1
4981·5	Erb+Y Tl	4 3	.		.	..
4900·0	Erb+y, Di+La	1 1	.	..	..	.
4882·5	Erb+y, Di+La	1 1	..		..	
5053·0	Tl Wo	3 1	.	.	..	.
5085·0	Tl Cd	4 1		.	.	..
4874·5	Pd Va	3 3		..	.	..
5177·0	Di+La Sb	4 3	..	.	..	..

TABLE IV, showing the number of lines belonging to each Metal widened in the SPOTS seen August 30th to September 3rd, 1879, and October 26th to November 7th, 1877.

Metals.	Total No. of Lines	Number of Lines common to Spots and Storms		Number of Lines affected in			Unaffected.	
				Spots		Storms (Young's)		
		1877. 26 Oct 7 Nov	1879. 30 Aug. 3 Sept.	1877. 26 Oct 7 Nov.	1879. 30 Aug. 3 Sept		1877. 26 Oct. 7 Nov.	1879. 30 Aug. 3 Sept
Sodium - - -	5	0	1	0	4	2	3	0
Magnesium - -	3	3	3	3	3	3	0	0
Zinc - - -	8	0	0	0	3	2	6	3
Cadmium - - -	2	0	0	0	0	0	2	2
Barium - - -	2	0	0	0	0	2	0	0
Calcium - - -	2	1	1	1	2	1	1	0
Nickel - - -	20	2	1	4	9	2	16	10
Iron - - -	96	5	14	7	77	20	74	13
Titanium - - -	58	0	0	4	20	6	18	32
Molybdenum - -	2	0	0	0	1	0	2	1
Tungsten - - -	7	0	0	0	2	0	7	5
Thorium - - -	2	0	0	0	1	0	2	1
Vanadium - - -	3	0	0	0	0	0	3	3
Antimony - - -	6	0	0	0	0	0	6	6
Bismuth - - -	7	0	0	0	1	0	7	6
Copper - - -	6	0	0	0	1	0	6	5
Thalium - - -	7	0	1	0	2	1	6	5
Erbium Yttrium - -	10	0	0	0	0	2	8	8
Cerium - - -	4	0	0	0	1	0	4	3
Palladium - - -	4	0	0	0	0	0	1	4
Didymium and Lanth-anum	15	0	0	0	0	0	15	15
Tellurium - - -	7	1	2	1	2	2	5	5
Total - -	276	12	23	20	129	43	225	127

APPENDIX G.

ON A METHOD OF DETECTING THE UNKNOWN INEQUALITIES OF A SERIES OF OBSERVATIONS BY PROFESSOR BALFOUR STEWART, F.R.S.*

1. Our chief reason for suspecting the existence of a connexion between the state of the solar surface (as this is revealed by spots) and the magnetism and meteorology of the Earth is derived from the fact that our observational series of sun-spots, on the one hand, and of magnetical and meteorological changes, on the other, are believed to be all subject to a common inequality, whose period (about 11 years) is virtually the same in all.

But as it is only of late years that observations of great accuracy have been made in these three branches of inquiry, it is impossible to compare together more than a few series of this long-period inequality, and hence some observers are still inclined to doubt the reality of a true connexion between the Sun and the Earth of the kind above-mentioned. We are thus led to ask ourselves whether there may not be other inequalities of shorter period in these various observations, and whether we cannot devise some means of ascertaining the exact periodical times of these as well as their other properties.

We might thus expect to decide the question regarding a connexion between these three branches, for if solar observations and those of terrestrial magnetism and meteorology all exhibit a series of inequalities that are essentially the same in each, it is impossible to call in question the reality of some connexion between them.

2. The researches of Broun, Hornstein, Buys Ballot, Baxendell, and others have indicated the probable existence of inequalities in magnetism and meteorology, with periods of comparatively short length. Messrs. De la Rue, Stewart, and Loewy have likewise observed indications of a short-period fluctuation in sun-spots; but I am not aware that any systematic attempt has yet been made to ascertain with great precision the exact period or periods of unknown inequalities either in terrestrial or in sun-spot observations.

3. In order to illustrate this method of detecting inequalities let us begin by taking a well-known case.

Suppose that we had in our possession extensive records of the temperature of the Earth's atmosphere at some one place in middle latitudes, and that, independently of astronomical knowledge, we were to make use of these for the purpose of investigating the natural inequalities of terrestrial temperature. We should begin by grouping the observations according to various periods taken, say, at small but definite time-intervals from each other. Now, if our series of observations were sufficiently extensive, and if some one of our various groupings together of this series should correspond to a real inequality, we should expect it to exhibit a well-defined and prominent fluctuation, whose departures above and below the mean should be of considerable amount. Suppose, for instance, that we have 24 points in our series, and that we group a

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* A description of this method has been given by the author in conjunction with Mr. Dodgson in a preliminary Report to this Committee, and in a second Report the method has been applied to terrestrial magnetism and meteorology. (See Pro R S, May 29, 1879, and Nov 20, 1879.) The progress of the subject since these preliminary Reports renders it desirable to recast their shape as well as to add other matter This is done in the present communication

long series of temperature observations in rows of 24 each, the time-distance between two contiguous members of one row being one hour The series would thus represent the mean solar day, and we should without doubt obtain from a final summation of our rows a result exhibiting a prominent temperature fluctuation of a well-defined character, which we might measure (as long as we keep to 24 points) by simply adding together all the departures of its various points from the mean, whether these points lie above or below; in fine, by obtaining the area of the curve which is the graphical representation of the inequality above and below the line of abscissæ taken to represent the mean of all the points Suppose next that, still keeping to rows of 24, we should make the time-interval between two contiguous members of a row somewhat different from one hour, whether greater or less, we should now in either case obtain a result exhibiting, when measured as above, a much smaller inequality than that given when the interval was exactly one hour; and it is even possible that, if our series of observations were sufficiently extensive, we should obtain hardly any traces of an inequality whatever. In fine, when each row accurately represented a solar day, the result would be an inequality of large amount, but when each row represented a period either slightly less or greater than a day, the result would be an inequality of small amount

4. This process, as far as I have described it, is not new, having been already used by Baxendell, and probably by other observers of stellar variability In the present case we should by its means, after bestowing enormous labour in variously grouping in accordance with a great number of periods taken at small intervals from each other, obtain definite results These might be graphically represented in the following manner. The line of abscissæ might be taken to denote the exact values of the various periods, forming a time-scale in fact; while the ordinates might represent the areas or summations obtained as above by employing these various periods There would thus be in the case now used for illustration a very prominent peak, corresponding to 24 hours, which would fall off very rapidly on either side

In this particular instance, having obtained as a result a period of exactly 24 hours, there would probably be no occasion to do anything more, because we have no reason to suppose the existence of any other temperature period very near to 24 hours in addition to the one exactly corresponding thereto

We might, therefore, proceed finally to evaluate the obtained inequality, which would represent the mean daily variation of temperature

5 It would be different, however, should there prove to be a number of inequalities having periods very close to one another on the time-scale. In this case, even when we had obtained a graphical representation of our results in the manner just now mentioned, it might be supposed that the various inequalities to some extent interfered with each other, affecting not only the position in the time-scale of the points of maximum inequality, but also the extent of range and the form of these inequalities. We should therefore have next to eliminate the effect of one inequality upon another.

The whole process would thus consist of two parts. In the first place, by enormous labour, we should have to obtain a graphical result showing the exact positions in the time-scale of the points of observed maximum inequality. We should then have to eliminate the effect of the various inequalities upon each other, provided it

be found that there are several such inequalities very close together. In the present appendix a method is exhibited by which the great labour of the first of these two processes is materially abridged.

6 Let us begin by making use of certain records of the Kew Observatory, which have been received through the kindness of the Kew Committee. In these the daily ranges of the magnetic declination are given after excluding disturbed observations by the process of Sir E Sabine. The daily ranges are given in inches, and they denote the differences between the greatest and least values of each day's hourly tabulations from the curve of the self-recording instrument, disturbances, as already mentioned, being excluded. These records extend from the beginning of 1858 to the end of 1873, embracing in all 16 years' observations.

7. Let us next group these Kew declination ranges in such a manner as to represent a period of 24 25 days It is unnecessary to describe the details of the method by which a series of daily observations may be grouped so as to represent a period that is not an exact number of days; suffice it to say that a long series of upwards of 240 rows is at length obtained, each embracing 24 horizontal figures. Nor is it necessary to give the reason which induced the selection of the precise period of 24·25 days, since for all practical purposes this may be regarded as a period chosen at random.

Having grouped the whole 16 years' observations according to this period, let us next break up these into yearly sets. Each of these sets will thus be freed from the influence of the well-known annual inequality of declination range.

These yearly sets will embrace generally 15 but sometimes 16 rows of 24 each.

The next operation is to sum up these 15 or 16 sets for each of the 24 vertical columns. It might naturally be supposed that we should then divide each of the sums so obtained by 15 or 16, as the case may be, and then find the difference of each of the 24 quotients from the mean of all the quotients, such differences, when placed together, representing the inequality for that year.

There appears, however, reason to believe that on those occasions when the daily range of the declination magnet is greatest the variations of this daily range are likewise greatest and possibly in nearly the same proportion. It is thus probably safer to adopt the following plan with respect to the yearly results; namely, to regard the mean of the 24 sums for each year as equal to 1,000, and to represent each individual sum upon this proportional scale

8. Adopting this plan the yearly inequality is, therefore, represented by the series made up of the differences of each of the 24 proportionally reduced sums from this normal value (1,000)

As it is desirable to represent each yearly inequality by means of a curve, this series of differences has been to some extent smoothed or equalised. The primary series (A) has been converted into another series (B), also of 24 sums, each sum of (B) being the mean of four consecutive sums of (A), and the series (B) has then been converted by a similar process into a series (C), each sum of which is a mean of four consecutive sums of (B). This amount of equalisation, by getting rid of what may be termed accidental fluctuation, is quite sufficient to enable a curve to be drawn, well representing each yearly inequality. The equalised yearly inequalities corresponding to the period 24·25 days are represented in Table I.

Table I.—Equalised Yearly Inequalities of Kew Declination-range corresponding to period 24 25 days

Year.	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1858	−38	−38	−35	−21	−15	0	+13	+23	+10	+14	+50	+41	+31	+21	+ 3	− 1	−11	−10	0	0	− 7	−18	−31	−41
1859	−20	−24	−27	−14	− 2	− 5	+ 6	+ 2	+ 4	+ 8	+22	+26	+23	+16	+ 7	+ 1	− 1	− 2	− 3	− 3	− 4	− 3	− 5	−12
1860	+34	+24	+ 6	−10	−27	−28	−20	−21	−22	−29	−31	−22	−19	− 8	+ 3	+ 7	+19	+22	+20	+21	+16	+18	+22	+28
1861	+25	+25	+25	+25	+28	−30	+33	+29	+26	+13	− 3	−19	−36	−46	−53	−50	−42	−34	−20	−12	0	+12	+18	+26
1862	+ 9	+13	+18	+24	+22	+14	+ 4	− 5	−17	−20	−19	−20	− 7	− 4	− 5	− 4	−10	− 7	− 7	− 1	+ 3	+ 4	+ 9	+ 6
1863	+10	+ 2	− 7	−18	−28	−35	−34	−26	−15	+ 5	+17	+21	+19	+ 7	− 2	− 6	− 5	− 3	+ 4	+11	+20	+24	+21	+18
1864	− 1	−12	−15	− 9	+ 9	+21	+18	+11	+ 5	+ 6	+13	+23	+26	+26	+20	+10	+ 2	−14	−29	−40	−12	−26	− 7	+ 5
1865	−11	− 7	− 2	− 7	− 3	− 4	+ 1	+13	+11	+ 1	−14	−18	−11	0	+ 9	− 1	− 7	− 7	+ 2	+15	+21	+17	+ 5	− 3
1866	−17	− 8	+ 3	+26	+35	+32	+23	+ 9	− 1	− 1	+ 2	+12	+20	+15	− 3	−22	−43	−46	−32	−15	+ 6	+ 9	+ 2	−11
1867	+14	+25	+29	+33	+28	+24	+22	+ 9	0	− 9	−22	−20	−24	−26	−16	−14	− 4	+ 5	+ 2	− 4	−14	−19	−15	− 4
1868	+24	+24	+21	+22	+18	+17	+ 6	−10	−20	−28	−22	−13	−10	− 9	− 6	− 3	+ 8	+ 6	− 7	−14	−11	−11	+ 8	+18
1869	+28	+28	+24	+19	+ 3	−13	−23	−36	−37	−33	−30	−24	−20	−17	−14	− 8	0	+ 6	+12	+22	+25	+30	+31	+27
1870	− 2	− 7	−10	− 9	−14	−17	−26	−29	−31	−32	−21	−14	− 5	+ 4	−16	+24	+32	+37	+30	+28	+20	+15	+11	0
1871	− 4	−13	−17	−14	+ 1	+21	+34	+14	−17	+12	+31	+20	+ 4	− 6	−13	−18	−17	−25	−33	−31	−31	−19	− 5	− 1
1872	+12	− 1	− 9	−13	−18	−17	−18	−16	−12	−10	− 5	−10	− 6	0	+ 7	+25	+27	+20	+12	+ 1	− 3	+ 8	+13	+13
1873	+27	+14	+ 6	− 2	− 3	− 2	0	+ 8	+17	+24	+24	+13	0	−17	−34	−39	−46	−40	−27	−16	+ 1	+21	+32	+30
	+90	+45	+10	+32	+34	+48	+44	+ 2	− 5	−16	− 5	− 4	−15	−44	−81	−99	−98	−92	−76	−38	− 5	+62	+109	+105
																							(sum=1162)	

9. A glance at the sums of this table for the whole 16 years will suffice to show that 24·25 days do not correspond to the exact period of any marked inequality. The sums are small, and we conclude therefore that we have not been fortunate in our chance selection of a period to begin with, but the peculiarity of this method is, that it will enable us to ascertain the true position in the time-scale of the neighbouring prominent inequalities by means of the results of Table I. The method of doing this can easily be rendered evident Each horizontal row of Table I consists of 24 numbers, and there are 16 years, beginning with 1858. We may, therefore, call the numbers of the first row $(0)_{58}$, $(1)_{58}$, $(2)_{58}$, &c., $(23)_{58}$, those of the second row $(0)_{59}$, $(1)_{59}$, $(2)_{59}$, &c., $(23)_{59}$, and so on for each row.

In this table, therefore, each vertical column consists of similar numbers for the various years, adopting the notation now mentioned.

Suppose, however, that we displace these values as follows.—

1858 . .	$(0)_{58}$	$(1)_{58}$	$(2)_{58}$	. . .	$(21)_{58}$	$(22)_{58}$	$(23)_{58}$
1859 . .	$(1)_{59}$	$(2)_{59}$	$(3)_{59}$	.	$(22)_{59}$	$(23)_{59}$	$(0)_{59}$
1860 . .	$(2)_{60}$	$(3)_{60}$	$(4)_{60}$	. . .	$(23)_{60}$	$(0)_{60}$	$(1)_{60}$
. .	.	.	.	. .	.	.	.
. .	.	.	.	. .	.	.	.
1873 . .	$(15)_{73}$	$(16)_{73}$	$(17)_{73}$	. .	$(12)_{73}$	$(13)_{73}$	$(14)_{73}$

Now, if we add up the various vertical columns of this series the sums will represent an inequality somewhat larger in period than 24·25 days. For it is manifest that if we have a regular series of waves whose values we plot numerically after the manner of Table I., the consequence of adopting too small a time-scale will be to throw any salient point of the wave, such as the crest, always further and further to the right, and to correct this we should have to pull the whole series a little to the left each time Now, this is precisely what we have done in the above process, which will thus give us the representation of an inequality of a larger period than 24·25 days. It is easy to find the exact length of period which the above series represents. We pull everything to the left nearly one day, but more accurately the 24th part of 24·25 days in one year. If, therefore, 365·25 days give $\frac{24·25}{24}$, what will 24·25 days give? We find from this proportion that the period of the inequality indicated by performing the above process is $24·25 + \frac{(24·25)^2}{24 \times 365·25}$ = 24·317 days. Again, we may pull things to the left two, three, or four divisions each year, and thus obtain the representation of inequalities with periods of 24·384, 24·451, or 24·518 days

Or we may perform the opposite operation of pushing things to the right one division each year, and thus obtain the representation of an inequality, having a period of 24·183 days, while 2, 3, or 4 such divisions each year would give us periods of 24·116, 24·049, or 23·982 days.

10. It has been found necessary to push things not merely by the multiple of a whole division, right or left each year, but by the multiple of half a division.

To accomplish this we must obtain for every alternate year a series of half-way points, which is best done by converting the series

of such years into curves, and using these to give us the half-way points.

For instance, should we wish to pull things to the left half a division each year, we should adopt the following arrangement:—

1858	. .	$(0\frac{1}{2})_{59}$	$(1\frac{1}{2})_{58}$	$(2\frac{1}{2})_{58}$	. .	$(21\frac{1}{2})_{59}$	$(22\frac{1}{2})_{58}$	$(23\frac{1}{2})_{58}$
1859	. .	$(1\ )_{59}$	$(2\ )_{59}$	$(3\ )_{59}$	. .	$(22\ )_{59}$	$(23\ )_{59}$	$(\ 0\ )_{59}$
1860	. .	$(1\frac{1}{2})_{60}$	$(2\frac{1}{2})_{60}$	$(3\frac{1}{2})_{60}$	. .	$(22\frac{1}{2})_{60}$	$(23\frac{1}{2})_{60}$	$(\ 0\frac{1}{2})_{60}$
1861	. .	$(2\ )_{61}$	$(3\ )_{61}$	$(4\ )_{61}$	.	$(23\ )_{61}$	$(\ 0\ )_{61}$	$(\ 1\ )_{61}$
.	.	.	.	.	.	.	.	.

11. The following plan has been found very useful in abridging the labour of these reductions.

Sixteen perfectly similar strips of thick paper are taken, one for each year. Each of these strips is divided into 48 small compartments, a vertical black line being ruled at the beginning, the middle, and the end. Upon the first of these strips the inequality, say for 1858, is written in duplicate, so that the second 24 figures are a repetition of the first. The same is done for the other years These strips are then attached to a frame which allows them to slide along with regard to each other, and at the same time only exposes 24 lines of figures at a time. By this method they can easily be arranged according to any given order, and the sums made with very little trouble.

It is further desirable to exhibit all the positive values, say, in black, and all the negative values in red, so that the eye may easily distinguish between them.

The following will exhibit the nature of the arrangement, only to save space I take an inequality consisting of only four terms.

			$(0)_{58}$	$(1)_{58}$	$(2)_{58}$	$(3)_{58}$	$(0)_{58}$	$(1)_{58}$	$(2)_{58}$	$(3)_{58}$
		$(0)_{59}$	$(1)_{59}$	$(2)_{59}$	$(3)_{59}$	$(0)_{59}$	$(1)_{59}$	$(2)_{59}$	$(3)_{59}$	
	$(0)_{60}$	$(1)_{60}$	$(2)_{60}$	$(3)_{60}$	$(0)_{60}$	$(1)_{60}$	$(2)_{60}$	$(3)_{60}$		
$(0)_{61}$	$(1)_{61}$	$(2)_{61}$	$(3)_{61}$	$(0)_{61}$	$(1)_{61}$	$(2)_{61}$	$(3)_{61}$			

The vertical portion between the brackets is here all that is exposed.

12. Before concluding this description it ought to be remarked that the method can only be considered as correct for periods not far removed on either side from that for which the series was originally framed. Thus, in the present instance, while the results of Table I. will readily indicate inequalities that lie six divisions (of 0·067 day each) either to the right or left of the normal series, it is apparent that + 12 divisions from the normal must necessarily exhibit the same result as — 12; it will not therefore do to push the method nearly so far.

13. When this method is applied to Table I. we obtain the following results:—

Table II.—Exhibiting the results of the above method applied to the numbers of Table I.

Divisions from normal.	Exact period in days.	Magnitude of inequality.
—8·0	23·7133	1438
—7·5	23·7469	1757
—7·0	23·7804	1546
—6·5	23·8140	1047
—6·0	23·8475	1698
—5·5	23·8810	1141
—5·0	23·9146	1002
—4·5	23·9481	2009
—4·0	23·9817	2954
—3·5	24·0152	3109
—3·0	24·0487	2504
—2·5	24·0823	1289
—2·0	24·1158	1068
—1·5	24·1494	1473
—1·0	24·1829	1700
—0·5	24·2165	1513
Normal	24·2500	1162
+0·5	24·2835	1115
+1·0	24·3171	1398
+1·5	24·3506	867
+2·0	24·3842	1062

14. The results of Table II. are exhibited graphically by means of a curve in Fig. I., which accompanies this paper.*

In this curve the abscissæ denote periods, while the ordinates represent corresponding inequalities. It will be noticed that we have indications of several maximum points, more especially of one corresponding very nearly to 24 days.

This has induced us to make a new series for 24 days in addition to the one for 24·25 days, the construction of which we have already described. Both have been treated in precisely the same manner.

The results of this series are given in Table III.

* This curve goes somewhat beyond the limits of the table.

Table III.—Equalised Yearly Inequalities of Kew Declination-range corresponding to period 24·00 days.

Year	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1858	−34	−48	−51	−16	−44	−31	−15	− 1	+19	+29	+35	+36	+36	+38	+31	+21	+ 7	− 9	− 4	+ 9	+17	+21	+ 5	−20
1859	−20	−26	−22	−24	−22	−18	−21	−17	−13	− 2	+ 9	+11	+17	+12	+15	+23	+22	+28	+25	+20	+16	+ 6	− 5	−12
1860	+ 5	+14	+18	+18	+16	+17	+19	+26	+39	+44	+41	+22	− 8	−34	−50	−49	−35	−21	−10	−10	−16	−19	−17	− 6
1861	−27	−47	−56	−62	−56	−15	−36	−21	− 6	+ 8	+15	+22	+24	+21	+29	+26	+27	+32	+30	+36	+38	+30	+17	− 3
1862	−24	−30	−22	−13	− 1	+ 6	+ 5	+ 1	− 1	0	− 2	− 5	−11	−17	−13	− 2	+10	+20	+25	+28	+27	+21	+ 8	− 8
1863	−17	−17	−23	−21	−15	0	+22	+32	+33	+24	+10	+ 4	+ 6	+ 3	+ 2	− 2	− 4	+ 6	+10	+ 8	− 4	−17	−21	−21
1864	+21	+ 8	0	− 9	− 7	0	+ 5	+ 1	− 2	− 5	− 9	− 6	− 8	− 4	+ 1	+ 6	+13	+ 9	+ 2	− 8	−17	− 7	+ 2	+16
1865	+ 2	0	− 3	− 5	− 4	− 5	−10	− 9	− 9	− 2	+14	+19	+26	+21	+ 4	+ 1	− 3	+ 2	+ 6	− 6	−12	−15	−11	0
1866	−34	−33	−17	− 5	+ 6	+ 8	− 4	−16	−19	−14	− 2	+20	+26	+24	+15	0	− 2	+ 2	+10	+22	+22	+13	− 3	−24
1867	−55	−40	−26	− 5	+14	+24	+30	+19	+ 6	+ 2	0	+ 8	+21	+26	+31	+30	+28	+30	+20	+ 6	−10	−40	−51	−56
1868	−27	−29	−23	−16	−13	−14	− 8	− 2	+ 1	+ 3	−10	−19	−23	−15	+ 5	+16	+28	+29	+31	+39	+33	+25	+ 5	−17
1869	0	−17	−20	−25	−27	−33	−40	−47	−48	−36	−24	− 8	+ 6	+11	+16	+23	+29	+32	+37	+41	+41	+43	+31	+15
1870	+ 2	+ 2	− 8	0	− 8	−17	−22	−31	−34	−25	−18	− 6	+ 6	+ 9	+12	+17	+22	+25	+24	+21	+12	+ 6	+ 6	− 2
1871	−12	0	+ 2	− 2	−11	−20	−10	+ 4	+20	+41	+46	+41	+34	+23	+15	+18	+16	+ 6	− 5	−30	−48	−51	−47	−31
1872	+14	+ 6	+ 3	0	+ 3	+ 8	+11	+ 8	+ 1	− 8	−19	−24	−19	−15	−10	− 6	−10	− 7	− 4	+ 1	+11	+16	+19	+21
1873	−27	−32	−38	−34	−22	− 5	−15	+30	+39	− 5	+21	+11	− 3	− 2	− 3	− 5	− 4	− 5	+ 7	−13	+16	+11	− 3	−14
	−233	−289	−281	−249	−191	−125	−59	−23	+26	+94	+107	+126	+130	+101	+100	+117	+144	+179	+204	+190	+126	+43	−65	−162
																							(sum=3364)	

15. When the method is applied to Table III, we obtain the following results:—

Table IV.—Exhibiting the results of the above method applied to the numbers of Table III.

Divisions from normal.	Exact period in days.	Magnitude of inequality.
−7 5	23·5072	1310
−7·0	23 5400	1280
−6 5	23 5729	2568
−6 0	23·6057	2710
−5·5	23 6386	2128
−5 0	23 6715	1070
−4 5	23·7043	674
−4·0	23·7372	1260
−3·5	23·7700	1500
−3·0	23·8029	922
−2·5	23·8357	1394
−2·0	23 8686	1976
−1·5	23·9014	1096
−1 0	23 9343	1754
−0·5	23 9671	2464
Normal	24·0000	3364
+0·5	24·0329	2960
+1·0	24·0657	1974
+1·5	24 0986	1032
+2·0	24·1314	1548
+2 5	24·1643	2174
+3 0	24·1971	2160
+3·5	24·2300	1664
+4 0	24 2628	1278
+4 5	24·2957	1570
+5·0	24·3285	1456
+5·5	24·3614	954
+6 0	24 3943	1110

16. The results of Table IV. are exhibited graphically by means of a curve in Fig. II *

It will at once be seen by comparing together the two curves (Figs. I and II.) that they both exhibit as nearly as possible the same positions for maximum inequalities. Thus, by selecting at random the period 24·25 days, we are by this method referred to nearly the true positions of the various maximum inequalities.

Before proceeding further it ought to be stated that the above series of observations of the Kew Declination Range has been given rather as having been that first employed for illustrating the method than as pretending to represent the best element to be discussed from a scientific point of view. Having employed this series to explain the details of the method, it has served its purpose, and we now proceed to apply the method to observations of sun-spots.

17. For this purpose, let us take daily values of total sun-spot areas and commence with Schwabe's observations which are recorded in Appendix B. These extend from 1832 to 1853 inclusive. From 1854 to 1860 inclusive we have for the same purpose Carring-

* This curve goes somewhat beyond the limits of the table

ton's more accurate observations, for 1861 we have to fall back once more upon Schwabe, while from 1862 to 1867 inclusive we have the Kew series of observations. These various series form, when put together, one whole series of 36 years. In many cases, owing to bad weather, there are gaps between consecutive observations—let us fill up such by the simplest possible form of interpolation One advantage of this application of the method will be that, provided we obtain good results with these 36 years, it will not merely prove the value of the method, but also of the sun-spot catalogues to which it has been applied, and, as 23 out of these 36 years are deduced from Schwabe's observations, the result of a successful application of the method to these will indicate the general trustworthiness of the numbers derived from Schwabe's pictures which are recorded in Appendix B. These 36 years' observations when the blanks are filled up by interpolation give us therefore one long series of more or less trustworthy daily records of the total area of spots on the sun's visible disc, the unit of measurement being the one millionth of the sun's visible hemisphere.

Of this series, the first 22 years' observations are, as above mentioned, recorded in Appendix B., the results from 1854 to 1860 inclusive, derived from Carrington's observations, have been published by Messrs. De La Rue, Stewart, and Loewy in a private memoir, those for 1861, derived from Schwabe, are again published in Appendix B , while those derived from the Kew series from 1862 to 1866 inclusive may be found in the transactions of the Royal Society for April 30, 1868, and March 10, 1870.

18. Let us now in the next place group together these sun-spot observations in series of 24 days after the manner already described; also for the purpose of comparison with similar series in magnetism and meteorology which have been communicated by this Committee to the Royal Society, let us so arrange our sets of 24 daily values that one of them shall begin with January 1st, 1858.

Let this long table so arranged be next split up into separate years. A year will thus contain generally 15, but occasionally 16 lines of 24 places each, that is to say, it will consist of 15 or sometimes 16 horizontal rows under one another, the number of places in each horizontal row being always 24. The sums of each of the 24 vertical columns for each year are next taken.

We have thus for each year a series of 24 sums. But it will at once be seen that these sums will be greater in years of maximum than in years of minimun sun-spots, so that to use them as they stand would virtually mean to give great weight to years of maximum as compared with years of minimum sun-spots in our search for inequalities.

We have endeavoured to overcome this difficulty in the manner already described in Art. 7. Indeed, if sun-spot observations be put into a graphical form, it will at once be seen that whenever the total sun-spot area is great, the oscillations of this or ranges of sun-spot inequalities are great also, so that these ranges may, as a first approximation at least, be deemed to be proportional to the general sun-spot activity. In other words, the oscillations of area are nearly proportional to the area. We have therefore taken the above-mentioned 24 numbers for every year, and proportionally altered each, so that the sum of the 24 shall for each year be equal to 24,000. Each sum for each year should therefore be equal to 1,000, provided it be not subject to the influence of some inequality. If, however, there be a 24 day inequality, some of these values will be larger and others smaller than 1,000, and it is their differences from

FIG. I. KEW DECLINATION RANGE 24·25 DAYS.
FIG. II. KEW DECLINATION RANGE 24·00 DAYS.
FIG. III. SOLAR SPOTTED AREA 24·00 DAYS.

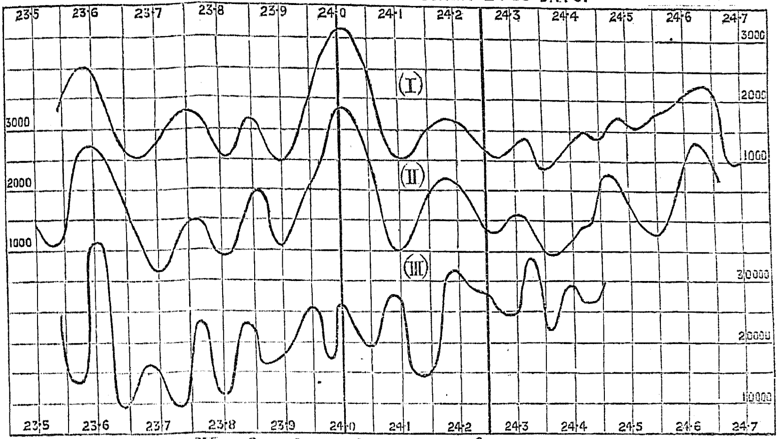


FIG. IV. SUN-SPOT INEQUALITY, $+\frac{2}{12}$ OR 24·011 DAYS.
FIG. V. TORONTO TEMP. INEQUALITY, $+\frac{4}{12}$ OR 24·022 DAYS.

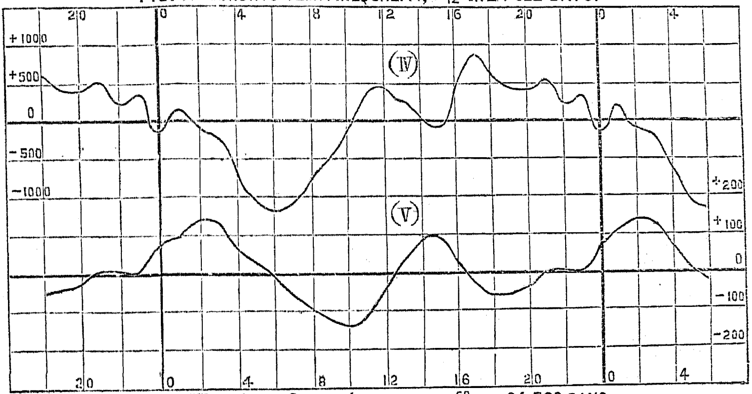
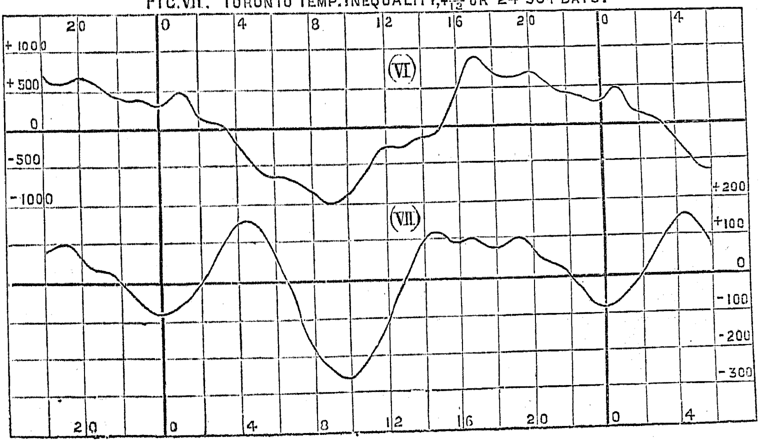


FIG. VI. SUN-SPOT INEQUALITY, $+\frac{50}{12}$ OR 24·329 DAYS.
FIG. VII. TORONTO TEMP. INEQUALITY, $+\frac{61}{12}$ OR 24·334 DAYS.



1,000 that are recorded with *plus* and *minus* signs in the following table, which is in this respect identical with Tables I. and III. Before exhibiting this table it will be necessary to make two remarks. In the first place, in certain minimum years the observations which exhibit sun-spots are sometimes too unfrequent to render the year tabulated as above in rows of 24 a trustworthy representative of the inequalities we are in search of. In such cases we have taken in addition, half a year on each side of the minimum year, so that we have thus the mean of two years instead of one, the central point of the series, however, being as before the middle of the minimum year.

This treatment has been applied to years 1833, 1844, 1855, and 1856.

It is also necessary to remark that it has not been deemed necessary to apply the equalisation described in Art. 8 to these sun-spot observations; but with this exception, the process already described has been exactly followed in obtaining Table V.

Table VI. has then been deduced from Table V. in the manner in which Table II. has been deduced from Table I.

The results of Table VI. are graphically represented in the diagram which accompanies this paper, Fig. III.

Table V.—Unequalised Yearly Inequalities of Sun-spots corresponding to period 24·00 days

Year.	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1832	−11	−120	−249	−374	−267	−41	−9	+157	+264	+289	+321	+122	+168	+43	+111	−23	+59	+109	−47	−178	−212	−181	−75	+141
1833	−404	−545	−575	−475	−431	−155	+29	+144	+231	+285	+577	+689	+592	+650	+704	+380	+77	+90	−151	−317	−379	−367	−261	−388
1834	−37	−289	−267	−388	−411	−295	−117	−68	−108	−54	−204	−332	−360	−63	+450	+402	+164	+104	+209	+82	+252	+354	+377	+309
1835	+226	+163	+169	+45	+6	+3	+94	+208	+95	+68	−39	−106	−145	−155	−158	−126	−165	−178	−129	+130	+37	+77	+27	+113
1836	−128	−75	−81	−65	−20	+79	+91	+208	+198	+229	+274	+315	+198	+115	+51	+25	−14	−150	−155	−115	−174	−258	−282	−236
1837	−99	−111	−109	−137	−87	−35	−48	−32	−47	−31	−41	+28	+80	+140	+205	+156	+21	−2	+16	−13	+28	+48	+103	−36
1838	+242	+364	+309	+252	+253	+219	+204	+198	−50	+49	+9	+11	−134	−193	−281	−287	−361	−169	−79	−36	−226	−85	−120	−89
1839	+114	+89	+170	+149	+3	−58	−37	−189	−177	−220	−247	−182	−203	−206	−191	−214	−110	−27	+110	+345	+397	+249	+229	+206
1840	−152	−63	+2	−46	−123	−126	−144	−18	+51	+74	−28	−118	−79	−38	+150	+72	−119	+3	+43	+165	+209	+219	+21	+15
1841	+118	+8	−2	+16	+78	+3	+243	+215	+176	+50	+110	+300	−49	+73	+37	+46	−56	−224	−211	−212	−204	−69	−286	−131
1842	−106	−86	−106	+88	+126	−21	+25	−116	−241	−111	−74	−279	−77	−16	−169	+63	+364	+91	−14	+177	+278	+88	+58	+58
1843	+166	−164	−264	−214	−237	−321	−306	−15	−122	+105	+238	+204	−160	−206	−95	+47	+380	+380	+308	+292	+177	−22	+120	−264
1844	+56	−40	−84	+61	+4	−24	+13	−119	−190	−154	−19	−74	−116	−168	−76	−81	+9	+127	+87	+185	+73	+123	+216	+191
1845	+39	+20	−62	+45	+94	+112	+107	+75	+39	−52	+172	+110	+63	−165	−260	−316	−230	−203	−215	+9	−70	+23	+190	+371
1846	+77	+117	+78	+22	−57	−163	−62	−102	−102	−121	−81	−64	+78	+62	+29	+173	−124	+79	+8	−48	−25	+22	+42	−91
1847	−63	−141	−114	−212	−241	−228	−126	−162	−56	−36	−7	+151	+57	+71	+194	+213	+139	+124	+163	+82	+26	+59	+27	+70
1848	−84	−47	−19	−13	−6	−25	−62	−152	−283	−177	−117	−55	−154	−109	−40	−124	+205	−257	+129	+147	−123	+291	+179	+8
1849	+52	+61	+70	+15	+29	+15	−49	−126	−34	−22	−103	−44	+10	−4	+0	+38	+95	+53	−39	−23	−33	+28	+1	−20

1850	+43	+120	+25	+135	+169	+109	+43	−60	−68	+36	+64	+150	−40	+44	−76	−81	−100	−76	−38	−29	−160	−114	−108	−8
1851	−69	−93	−140	−151	−154	−209	−266	−65	−51	−85	−113	+14	+91	+8	−11	+115	+181	+229	+176	+227	+135	+70	+76	+85
1852	−13	−103	−171	−175	−225	−273	−244	−294	−301	−281	−51	+48	+32	+155	+222	+224	+203	+236	+296	+246	+224	+18	+51	+176
1853	+163	+153	+161	+83	+52	−112	−89	−161	−225	−282	−237	−300	−175	−57	+6	+119	+127	+98	+62	+103	+64	+84	+216	+147
1854	+57	+74	−62	−112	−186	−256	−327	−224	−155	+88	+235	+122	+166	+130	+115	+76	+189	+317	+184	−15	−108	−201	−139	+32
1855	+517	+213	+128	+109	+135	−183	−464	−375	−230	−201	−266	−317	−301	−318	−254	−218	−111	+158	+111	+174	+357	+431	+440	+465
1856	+15	+147	+44	+53	+63	+10	+198	+191	+472	+371	+179	+197	+105	−273	−342	−327	−424	−412	−317	−66	+135	+177	−53	−143
1857	−159	−15	−58	−16	−216	−252	−68	+105	+131	+203	+291	+595	+515	+481	+276	−166	−182	−195	−293	−199	−218	−218	−181	−166
1858	−49	+28	+99	+130	+106	+65	+45	+9	+8	+41	+100	+52	−22	−14	−42	−128	−181	−194	−84	−13	−5	+96	−2	−45
1859	−84	−99	−131	−136	−149	−108	−66	−52	−35	−42	−6	+28	+62	+105	+115	+153	+191	+193	+167	+96	+17	−48	−99	−72
1860	+151	+57	−28	−4	−30	−77	−162	−255	−255	−232	−224	−42	−22	−3	+76	+126	+150	+144	+78	+84	+100	+118	+136	+114
1861	−169	−140	−179	−94	−51	−25	−106	−52	−76	−109	−62	+157	+177	+183	+176	+155	+74	+94	+35	+3	+89	+58	+38	−176
1862	+1	−18	−37	−13	+79	+80	−84	−55	−71	−78	−124	−66	−22	+65	+28	+2	+12	+63	+112	+165	+83	−21	−83	−68
1863	−314	−287	−119	+88	+137	+76	+17	−16	+25	+24	+48	+180	+148	+113	+20	+0	+5	+17	−21	+128	+73	−55	−94	−143
1864	+29	+80	+98	+63	+97	+139	+143	+136	+125	+86	+6	−28	+66	+12	−19	−47	−16	−59	−97	−130	−155	−210	−180	−139
1865	−391	−201	−320	−207	−111	−62	+40	+116	+218	+255	+286	+214	+264	+420	+416	+246	+118	−38	−111	−143	−190	−180	−277	−362
1866	+84	+339	−37	−156	−61	+61	+46	+30	−35	−55	−78	−84	−112	−154	−114	−106	−62	−39	−17	+81	+125	+168	+114	+62
1867	+229	−102	−204	−255	−265	−279	−274	−258	−241	−224	−234	−202	−233	−62	+58	+141	+201	+144	+149	+267	+363	+444	+402	+435
	+47	−706	−2065	−1942	−1877	−2357	−1722	−1204	−1120	−202	+552	+1394	+468	+666	+1311	+981	+973	+1147	+425	+1331	+1206	+1127	+1023	+544 (sum=26390)

Table VI.—Exhibiting the results of the above method applied to Table V.

Divisions from normal.	Exact period in days.	Magnitude of inequality (sum for 36 years)
−7·0	23·5400	23564
−6·5	23·5729	13271
−6·0	23·6057	36406
−5·5	23·6386	9335
−5·0	23·6715	15830
−4·5	23·7043	11977
−4·0	23·7372	9386
−3·5	23·7700	23317
−3·0	23·8029	11070
−2·5	23·8357	23595
−2·0	23·8686	16318
−1·5	23·9014	17921
−1·0	23·9343	22812
−0·5	23·9671	23205
0·0	24·0000	26390
+0·5	24·0329	20265
+1·0	24·0657	24116
+1·5	24·0986	27649
+2·0	24·1314	14568
+2·5	24·1643	17605
+3·0	24·1971	32232
+3·5	24·2300	28601
+4·0	24·2628	26898
+4·5	24·2957	24283
+5·0	24·3285	33884
+5·5	24·3614	22115
+6·0	24·3943	29390
+6·5	24·4271	26603
+7·0	24·4600	30018

19. From Table VI. it will be seen that there are evidences of at least 10 inequalities within the narrow time limits embraced by it. Thus these inequalities seem to be much crowded up together, and in certain regions it may be questioned whether there are sufficient points to enable us to represent the true progress by means of a curve, and thus to detect all the inequalities there present. Again, even in those cases where the inequality may be clearly indicated by such a curve, it may be so influenced by other inequalities near it in the time-scale that 36 years may not be sufficient to clear it from such influences, and we may thus have to resort to some method of elimination in order to do so.

20. With the view of exhibiting such a process let us take that inequality very near 24 days, and let us increase the number of points of our curve by obtaining values for every twelfth of a division on either side of 24 days. Referring to the method already described by which we slide the various yearly strips in a frame (Art. 11), we may by its means very easily obtain points for every $\frac{1}{12}$ of a division. For we may keep the slips of the first four years at the same phase, then slide the next four so as to differ from the first four one division; then slide the third four so as to differ from the second four one division, and so on. By this means we

shall obtain values corresponding to a change of one division every four years, or $\frac{1}{4}$th or $\frac{3}{12}$th of a division each year with sufficient accuracy.

Again, inasmuch as the whole 36 years have while deducing from them Table VI. been split up for convenience into three series of 12 years each, we may take any three such series and slide the second of these so as to differ one point in phase from the first, and the third so as to differ one point from the second, and thus obtain, by summing up, an inequality corresponding to a period which differs from that of the original inequality before being so treated by $\frac{1}{12}$th of a division on either side.

21. Performing this operation for the region round about 0·0 we obtain as follows:—

Table VII.—Exhibiting in detail the district on either side of 0·0 (24 days):—

Period.	Magnitude.	Period.	Magnitude.
$-\frac{12}{12}$	22812	$+\frac{1}{12}$	27208
$-\frac{11}{12}$	25104	$+\frac{2}{12}$	30326
$-\frac{10}{12}$	26276	$+\frac{3}{12}$	25923
$-\frac{9}{12}$	25580	$+\frac{4}{12}$	23802
$-\frac{8}{12}$	25396	$+\frac{5}{12}$	20813
$-\frac{7}{12}$	23337	$+\frac{6}{12}$	20265
$-\frac{6}{12}$	23205	$+\frac{7}{12}$	17245
$-\frac{5}{12}$	22457	$+\frac{8}{12}$	16949
$-\frac{4}{12}$	19322	$+\frac{9}{12}$	17997
$-\frac{3}{12}$	14956	$+\frac{10}{12}$	20939
$-\frac{2}{12}$	15484	$+\frac{11}{12}$	20354
$-\frac{1}{12}$	26750	$+\frac{12}{12}$	24116
$\frac{0}{12}$	26390	$+\frac{13}{12}$	21364

In this district, therefore, the maximum is at $+\frac{2}{12}$, and it is this inequality which we now wish to represent after having cleared it from the influence of neighbouring inequalities. Of these there are first of all three large but distant inequalities beyond the above district, the positions of which we may suppose to be given with sufficient precision by Table VI., namely, those at $-\frac{30}{12}$, $+\frac{18}{12}$, and $+\frac{36}{12}$. There are next inequalities at $-\frac{10}{12}$ and $+\frac{12}{12}$, which are perhaps sufficiently well indicated above in Table VII. There is also another inequality indicated by the above table, which, after eliminating the influence of its neighbour, is found to be at $-\frac{6}{12}$. It thus appears that there are probably six inequalities, the effects of which ought to be eliminated from $+\frac{2}{12}$, and these have the positions, $-\frac{30}{12}$, $-\frac{10}{12}$, $-\frac{6}{12}$, $+\frac{12}{12}$, $+\frac{18}{12}$, $+\frac{36}{12}$.

22. Let us now correct the inequality ($+\frac{2}{12}$) for the effects of these six neighbouring inequalities, taking the latter as they stand.

It will be unnecessary to describe in detail the method of applying this correction. Suffice it to say that the influence of the neighbouring inequalities is obtained and algebraically deducted.

When these corrections have been applied we get the following result:—

Period.	Corrected magnitude.
$+\frac{1}{12}$	29921
$+\frac{2}{12}$	32435
$+\frac{3}{12}$	30851

It thus appears that after a first elimination the position of this inequality is not altered

In the following table we have recorded the result of the process of elimination not merely for the sum of the whole 36 years, but for every four years, thus splitting up the whole series into nine sets, each of which is separately recorded in Table VIII.

It ought here to be mentioned that not merely Table V., but Table VIII and all other tables in this appendix exhibiting inequalities, are so arranged that the *starting point or epoch* is January 1st, 1858, that is to say, the first member of each inequality corresponds to January 1st, 1858.

Table VIII.—Exhibiting Sun-spot Inequality ($+\frac{2}{12}$), period 24·011 days for every four years from 1832 to 1867

1832–35	+201	+367	+405	+165	−226	−471	−805	−833	−700	−51	+114	−17	+18	−163	−59	−257	−40	+465	+645	+146	−112	+516	+165	+223
1836–39	−107	−271	−160	−70	−172	−312	−485	−565	−284	−176	−139	+102	+179	+256	+279	+218	−178	+291	+239	+227	+222	+344	+20	+50
1840–43	−515	−45	−317	−408	−159	−190	−488	−594	−299	−440	−73	+125	0	+126	+19	+154	+625	+1101	+416	+138	+279	+292	−44	+154
1844–47	+136	+326	−181	−407	−720	−518	−507	−221	−155	−94	−137	+24	+532	+145	+366	+170	+300	+106	+108	+152	−38	+97	−45	+117
1848–51	−261	−172	−262	+60	+205	+122	+151	+259	+96	+267	+377	+421	+292	−45	−454	−382	−212	−96	−54	−96	−235	−171	+45	+6
1852–55	+300	+66	−58	−131	−515	−999	−633	−463	−301	−341	−251	−172	−160	+125	+204	+419	+733	+483	+251	+245	+109	−6	+370	+586
1856–59	−182	+187	+114	+235	+69	−91	+123	+103	+335	+373	+103	+374	+393	+4	−109	−360	−467	−335	−299	−60	+55	−76	−245	−383
1860–63	+79	+104	+298	+156	−51	−391	−510	−552	−658	−486	−38	+63	−95	−63	+7	−83	+72	+353	+268	+378	+435	+357	+85	+145
1864–67	−83	−55	−62	−160	−280	−361	−240	−280	−275	−129	−147	+106	+130	+62	+5	−137	+162	+287	+311	+250	+337	+200	+371	+211
Sum -	−432	+507	−223	−560	−1849	−3211	−3391	+3149	−2241	−1377	−191	+1036	+1289	+717	+258	−258	+1291	+2598	+1883	+1380	+1279	+1553	+722	+1107
Four years' mean	−48	+56	−25	−62	−205	−357	−377	−350	−249	−153	−21	+115	+143	+83	+29	−29	+143	+289	+209	+153	+142	+173	+80	+123

23. It will, we think, be acknowledged that in Table VIII. there are evident traces of repetition which induce us to think that the above method has been successful in representing a true solar inequality.

Let us further apply the test described by General Strachey (Pro R S, May 31, 1877). In the first place, the mean difference of the individual observations of Table VIII from the mean of the whole series is found with sufficient accuracy by taking the mean of the various numbers in that table (216 in all) without respect of sign, inasmuch as the mean of the whole is according to our method equal to 0.

This mean difference is then found to be $= 248$.

In the next place, the mean difference of the individual observations from the respective calculated four years' means shown in the last line of Table VIII. is found to be $= 194$. The difference is, therefore, reduced in the proportion of 1 to 0 78.

It thus appears that the supposed law of variation obtained as in Table VIII gives a decidedly closer approximation to the actual observations than is got by taking the mean of the whole as the most probable value

The mean inequality of Table VIII. is graphically represented in Figure IV. of the diagram which accompanies this paper

24. I have next subjected to similar treatment the region about $+\frac{60}{12}$. We thus obtain :—

Table IX.—Exhibiting in detail the district around $+\frac{60}{12}$.

Period.			Magnitude of inequality	Period.			Magnitude of inequality.
$+\frac{12}{12}$	-	-	28601	$+\frac{57}{12}$	-	-	22996
$+\frac{13}{12}$	-	-	33205	..	-	-	....
$+\frac{41}{12}$	-	-	36452	$+\frac{59}{12}$	-	-	31278
$+\frac{45}{12}$	-	-	36186	$+\frac{60}{12}$	-	-	33881
$+\frac{16}{12}$	-	-	34348	$+\frac{61}{12}$	-	-	36232
$+\frac{17}{12}$	-	-	28248	$+\frac{62}{12}$	-	-	36163
[illegible]	-	-	26888	$+\frac{63}{12}$	-	-	33480
$+\frac{49}{12}$	-	-	24966	...	-	-	....
...	-	-	....	$+\frac{66}{12}$	-	-	22115
$+\frac{53}{12}$	-	-	23077	...	-	-	....
$+\frac{54}{12}$	-	-	24272	$+\frac{71}{12}$	-	-	32184
$+\frac{55}{12}$	-	-	24588	$+\frac{72}{12}$	-	-	29390
$+\frac{56}{12}$	-	-	22964				

In this district let us take the inequality at $+\frac{61}{12}$, and endeavour to eliminate from it the influence of neighbouring inequalities. Besides one at $+\frac{46}{12}$, which is sufficiently evident from Table VI, we see from Table IX. that there are inequalities at $+\frac{41}{12}$, + [illegible], and $+\frac{71}{12}$, so that it will be necessary to eliminate the influence of these four from the inequality at $+\frac{61}{12}$, which we wish to exhibit in a state of purity.

25. When this has been done we obtain the following result :—

Period.			Corrected magnitude.
$+\frac{59}{12}$	-	-	33897
$+\frac{60}{12}$	-	-	34835
$+\frac{61}{12}$	-	-	34535

The position of the inequality is now therefore as nearly as possible at $+\frac{60}{12}$, or at least nearer $+\frac{60}{12}$ than $+\frac{61}{12}$.

In Table X. the results of this elimination are given as before for every four years.

It will be acknowledged that in Table X. there are evident traces of repetition.

Again (applying General Strachey's test), the mean difference of the individual observations of Table X. from the mean of the whole series is found to be 243, while their mean difference from the respective calculated four-years' means is found to be 192. The difference is therefore reduced in the proportion of 1 to 0·78. These tests are thus in favour of the reality of the period given in Table X.

The mean inequality of Table X. is graphically represented in Fig. VI. of the diagram which accompanies this paper.

Table X.—Exhibiting Sun-spot Inequality ($+\frac{60}{12}$), period 24·329 days for every four years from 1832 to 1867.

1832–35	+88	+6	−102	−299	−363	−456	−391	−122	−235	−108	−653	−590	−150	+280	+84	+19	+478	+750	+689	+490	+785	+345	+10	−199
1836–39	+519	+319	+500	+509	+250	+87	−138	−195	−276	−407	−889	−771	−697	−537	−429	−281	−38	+83	−63	+270	+455	+609	+424	+639
1840–43	−585	+65	−112	−429	−329	−161	−180	−242	−179	−221	+248	+661	+717	+284	−106	+107	−56	+229	+140	+291	−207	−82	+61	−234
1844–47	−22	+204	+198	+72	−184	−346	−278	−162	−317	−596	−83	−84	+71	+353	+382	+18	+109	−61	+108	+195	+123	−6	+92	+184
1848–51	+145	+322	+171	+197	+67	−292	−495	−518	−517	−434	−286	−108	−185	−182	−171	+13	+222	+420	+239	+302	+387	+373	+184	+86
1852–55	+288	+111	+17	+275	−44	−150	−84	−209	−354	−314	−253	−147	−160	−155	−63	−32	−34	+348	+225	−89	−99	+261	+359	+274
1856–59	+12	+2	−149	−123	+71	−100	−264	−595	−430	−210	−341	−312	−345	−372	+120	+172	+763	+779	+348	+173	+416	−60	−2	+112
1860–63	+22	−83	−216	−185	−227	−122	−199	−107	−77	−106	+19	+54	+157	+97	+68	+114	+211	+79	+89	+20	+154	+83	+19	+106
1864–67	+428	+511	+212	+210	+208	+75	+15	+177	−22	−247	−248	−255	−193	−459	−374	−275	−112	+20	−26	−61	+57	+107	+88	+164
	+895	+1457	+429	+227	−551	−1465	−2014	−1973	−2407	−2943	−2486	−1615	−785	−691	−489	−145	+1548	+2647	+2079	+1891	+2071	+1630	+1235	+1132
Four years' mean	+99	−165	−48	−25	−61	−163	−224	−219	−267	−327	−276	−175	−57	−77	−54	−16	+172	+294	+231	+210	+230	+181	+137	+123

26. The result of the trial which has now been made of this method has been, I think, to show *firstly*, that by its means we may succeed in detecting unknown inequalities in a series of observations, and, *secondly*, that in all probability there are several such inequalities with periods near 24 days in sun-spot observations, whatever be the cause or causes of such.

It ought to be stated that the results now exhibited are not to be regarded as having reached their final state of accuracy, and this for two reasons

In the first place, if the Solar Physics Committee should ultimately bring together and edit all the good observations of sun-spots now extant, the series of original observations from which the results now recorded have been derived would thus be rendered more complete and trustworthy. In the next place, the method itself has only been carried to a first stage of approximation; and indeed it would have been undesirable to have attempted anything very laborious before having a final and complete series of trustworthy observations on which to operate.

The results are therefore to be viewed as only approximations.

27. The hypothesis of a connexion between sun-spots and terrestrial meteorology being still under debate, besides being one of great scientific interest as well as of possible practical importance, I have applied the method now described in the hope that it may contribute towards a solution of this pressing question I have selected the daily temperature range as that element which is most likely to exhibit the effects of solar variation, and Toronto as the best locality, inasmuch as American weather may, perhaps, be more directly influenced by the sun than European weather, which latter may be supposed to be influenced not merely by the sun, but also by the passage of weather from America.

Owing to the kindness of the Meteorological Council, of the Kew Committee, and of Messrs Kingston and Carpmael, the late and the present directors of Toronto Observatory, I have obtained 36 years of the diurnal temperature ranges at Toronto, extending from the beginning of 1844 to the end of 1879.

These have been split up for convenience into three series of 12 years each, the first and second of these being coterminous with the second and third of the 12 years' series of solar observations.

Table XI —Equalised Yearly Inequalities of Toronto diurnal Temperature Range corresponding to period 24·00 days

Year.	(0)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
1844	−36	−17	−39	−19	+8	+14	+7	−11	−24	−39	−48	−39	−29	−11	+15	+18	+20	+32	+28	+45	+62	+50	+37	+6
1845	+20	+27	+24	+22	+27	+31	+30	+24	+18	+16	+25	+38	+41	+22	−9	−47	−76	−79	−67	−52	−29	−18	−2	+14
1846	+52	+53	+57	+80	+86	+92	+90	+68	+60	+14	+21	−8	−49	−87	−107	−109	−97	−84	−70	−62	−51	−19	+9	+31
1847	−44	−24	−23	+2	+20	+49	+80	+87	+71	+31	−15	−44	−55	−39	−8	+4	+11	+6	−5	+6	−2	−24	−29	−55
1848	+40	+64	+99	+93	+72	+28	−39	−81	−98	−92	−46	−2	+36	+60	+40	+7	−25	−58	−55	−10	−26	−1	+1	+23
1849	+19	+7	+21	+41	+30	+29	+8	−35	−38	−28	−18	−9	+15	−4	−22	−40	−43	−25	−4	+11	+17	+21	+15	+14
1850	−9	−18	−14	−14	−16	−14	−13	−35	−33	−23	−19	+17	+37	+42	+55	+58	+53	+49	+35	−3	−31	−37	−14	−23
1851	−19	−18	+25	+54	+44	+35	+26	+29	+60	+77	+81	+52	+8	−46	−78	−78	−64	−26	+1	+11	+2	−22	−56	−68
1852	+115	+126	+111	+62	+9	−24	−51	−42	−44	−50	−52	−64	−64	−53	−40	−37	−33	−30	−25	−3	+15	+11	+58	+85
1853	+16	+1	−14	−14	−27	−56	−81	−106	−103	−50	+3	+65	+103	+91	+84	+56	+29	+17	−9	−12	−18	−3	+17	+11
1854	+12	+24	+39	+33	+23	+12	−16	−30	−35	−31	+2	+31	+45	+44	+15	−8	−22	−25	−20	−21	−24	−23	−20	−5
1855	+5	+4	−7	−9	−24	−45	−55	−62	−62	−42	−15	+4	+24	+18	+3	−9	−11	+8	+31	+62	+68	+57	+43	+14
1856	−59	−59	−57	−44	−25	−6	+44	+63	+68	−63	+44	+35	+30	+22	+13	+5	−5	−3	+5	−3	−10	−29	−49	−55
1857	−32	+6	+17	+15	−1	−42	−75	−98	−84	−54	−2	+53	+76	+102	−95	+69	+50	−25	−16	+14	−9	−36	−51	−54
1858	−36	−51	−62	−70	−66	−40	+1	+55	+85	+85	+62	+20	−11	−25	−34	−27	−28	−22	−5	+24	+56	+53	+39	−3
1859	−22	−24	−14	+7	+21	+20	0	−30	−47	−48	−42	−18	+2	+17	+49	+69	+87	+79	+34	−3	−40	−44	−27	−26
1860	−18	−1	+15	−6	+5	−11	−21	−2	+3	+17	+41	+52	+77	+93	+91	+68	+29	−15	−61	−90	−97	−82	−65	−34
1861	−13	−15	−20	−30	−16	−2	+16	+33	+18	+1	−17	−26	−14	−7	+8	+9	+2	+12	+9	+11	+23	+11	+4	+3

1862	+27	+65	+90	+80	+65	+27	−20	−33	−18	+5	+45	+62	+57	+33	−12	−50	−74	−79	−71	−65	−56	−52	−32	0
1863	−41	+22	+1	−3	−4	−1	+10	+8	−2	−18	−53	−81	−98	−109	−93	−71	−29	+19	+48	+85	+93	+86	+87	+64
1864	−15	−4	+14	+40	+59	+68	+59	+35	+4	−17	−24	−20	−17	−20	−24	−23	−7	+0	+8	−4	−24	−36	−33	−28
1865	−83	−83	−68	−35	+3	+34	+66	+84	+88	+77	+45	+8	−22	−15	−43	−35	−12	+15	+31	+45	+27	−2	−31	−67
1866	+15	−16	−36	−59	−55	−36	−15	+16	+28	+31	+27	+4	−14	−26	−26	−14	+11	+17	+5	+9	+14	+30	+45	+45
1867	−26	−16	−11	+9	+28	+25	+23	+22	+30	+43	+45	+41	+25	+8	+9	+5	−5	−17	−36	−51	−51	−13	−31	−26
1868	+29	+9	−11	−7	+6	−12	−15	−39	−79	−91	−95	−85	−47	−12	−17	−10	−5	+4	+56	+87	+96	+102	+82	+54
1869	−57	−57	−48	−30	+9	+44	+60	+76	+77	+57	+43	+15	−11	−25	−27	−12	+7	+16	+14	−7	−22	−35	−43	−41
1870	−48	−53	−52	−47	−38	−26	−35	−29	−31	−39	−24	−17	+5	+42	+60	+79	+83	+76	+67	+45	+24	+1	−17	−31
1871	−31	+6	+2	−18	−14	−7	−12	−21	−29	−33	−43	−50	−54	−46	−16	+9	+28	+34	+33	+34	+39	+46	+35	+46
1872	−68	−57	−48	−24	+16	+57	+95	+95	+66	+12	−33	−50	−40	−5	+19	+30	+24	+18	+19	+13	+2	−26	−52	−63
1873	−66	+39	+13	−22	−25	−16	−16	−1	−9	−30	−32	−53	−67	−75	−80	−57	−30	+7	+35	+41	+66	+75	+79	+92
1874	+61	+41	+10	−23	−55	−61	−65	−74	−67	−55	−37	−10	+8	+12	+26	+30	+31	+36	+24	+17	+23	+26	+42	+60
1875	+6	+9	+21	+11	+8	+2	−9	0	−4	+4	+14	+17	+26	+17	+4	−28	−58	−57	−48	−8	+22	+25	+18	+8
1876	+37	+68	+99	+99	+93	+78	+51	+30	−13	−47	−75	−93	−86	−76	−63	−46	−27	−21	−9	+4	−4	−2	−4	+7
1877	−12	−11	−10	−2	+31	+39	+57	+62	+44	+28	−4	−33	−56	−71	−71	−67	−53	−28	+6	+29	+46	+42	+23	+11
1878	−60	−56	−35	−4	+18	+31	+38	+41	+36	+24	+17	−2	−12	−4	−5	−1	+1	0	+8	+21	+17	+5	−23	−55
1879	−35	−18	−5	+29	+38	+33	+32	+6	−4	−18	−28	−25	−22	+7	+30	+45	+53	+27	+5	−11	−31	−31	−33	−44
	−130	−57	+84	+215	+358	+361	+255	+105	−68	−190	−207	−197	−156	−156	−159	−208	−185	−60	+33	+177	+187	+96	−8	−90 (sum=3742)

These have been treated precisely in the way in which the solar observations have been treated, except that the equalisation indicated in Art 8 has been applied to the Toronto temperature ranges while it has not been applied to sun-spots.

In Table XI we have a record of the yearly inequalities so obtained.

28 Let us next make use of the preceding table to obtain in detail, values indicating the positions of inequalities round about 0 0 (24 days). We thus get the following result —

Table XII.—Exhibiting in detail the district on either side of 0 0 (24 days).

Period.	Magnitude	Period	Magnitude
$-\frac{17}{12}$	6682	$\frac{0}{12}$	3742
$-\frac{16}{12}$	7434	$+\frac{1}{12}$	4206
$-\frac{15}{12}$	7624	$+\frac{2}{12}$	4192
$-\frac{14}{12}$	7136	$+\frac{3}{12}$	4878
$-\frac{13}{12}$	6618	$+\frac{4}{12}$	4308
$-\frac{12}{12}$	5766	$+\frac{5}{12}$	4752
$-\frac{11}{12}$	5086	$+\frac{6}{12}$	4932
$-\frac{10}{12}$	4828	$+\frac{7}{12}$	5718
$-\frac{9}{12}$	4054	$+\frac{8}{12}$	6602
$-\frac{8}{12}$	3438	$+\frac{9}{12}$	6286
$-\frac{7}{12}$	2852	$+\frac{10}{12}$	5516
$-\frac{6}{12}$	3976	$+\frac{11}{12}$	4526
$-\frac{5}{12}$	5230	$+\frac{12}{12}$	3200
$-\frac{4}{12}$	6460	$+\frac{13}{12}$	1944
$-\frac{3}{12}$	6366	$+\frac{14}{12}$	2330
$-\frac{2}{12}$	4546	$+\frac{15}{12}$	3082
$-\frac{1}{12}$	3498	$+\frac{16}{12}$	4158
		$+\frac{17}{12}$	6118
		$+\frac{18}{12}$	7132
		$+\frac{19}{12}$	7758
		$+\frac{20}{12}$	8116
		$+\frac{21}{12}$	7506

29. We see from this table that there are evidences of well marked inequalities at $-\frac{15}{12}$, $-\frac{4}{12}$, $+\frac{3}{12}$, $+\frac{8}{12}$, $+\frac{20}{12}$.

Let us take the one nearest 0·0, namely, that at $+\frac{3}{12}$, and eliminate from it the effect of the others noted above. As it seemed evident that the temperature results could not bear to be split up into series of four years, I have confined myself, as far as they are concerned, to three series of 12 years each, and for this purpose it will not be necessary to make the elimination so elaborate as in the case of sun-spots, so that we need not proceed beyond $-\frac{15}{12}$ on the one side and $+\frac{20}{12}$ on the other; that is to say, we may confine ourselves to the elimination above indicated.

When this has been made we obtain the following result:—

Period.	Corrected Magnitude.
$+\frac{3}{12}$	4300
$+\frac{1}{12}$	4579
$+\frac{5}{12}$	3791

From this it will be seen that the position of the inequality is now shifted to $+\frac{1}{12}$. As the present elimination is not so elaborate as that for sun-spots we need not probably proceed further.

30. It thus appears that there is a Toronto temperature range inequality corresponding in time scale to $+\frac{1}{12}$, while there is a sun-spot inequality corresponding in time scale to $+\frac{2}{12}$. This nearness in place is in favour of the hypothesis that the two inequalities are really identical in period, the terrestrial being probably caused by the celestial.

31. Let us next endeavour to see how far these two correspond in type. For this purpose we have given the values of the two inequalities for each 12 yearly series in Table XIII., and here, for temperature range as well as for sun-spots, the starting point is January 1st, 1858; that is to say, the first member of each inequality corresponds to that date.

Table XIII.—Comparing together the Sun-spot Inequality $+\frac{2}{12}$, and the Toronto Temperature Range Inequality $+\frac{4}{12}$.

$+\frac{2}{12}$=24·011 days (Sun-spots)

1832–43	−121	+51	−72	−313	−557	−973	−1778	−1995	−1283	−667	−98	+210	+197	+219	+239	+115	+763	+1800	+1298	+511	+613	+1152	+141	+127
1844–55	+175	+220	−501	−478	−1030	−1395	−989	−425	−360	−168	−11	+283	+661	+525	+116	+207	+821	+493	+305	+301	−159	−80	+370	+709
1856–67	−186	+236	+350	+231	−262	−843	−627	−729	−598	−542	−82	+543	+428	+3	−97	−580	−293	+307	+280	+568	+825	+181	+211	−29
12 years' mean.	−144	+169	−74	−187	−616	−1070	−1131	−1050	−747	−459	−64	+345	+430	+249	+86	−86	+430	+866	+628	+460	+426	+518	+241	+369

$+\frac{4}{12}$=24 022 days (Toronto Temperature Range).

1844–55	+162	+60	+80	+43	−17	+4	−54	−120	−191	−271	−323	−232	−59	+98	+223	+210	+111	−15	−53	−51	+9	+127	+137	+151
1856–67	−136	0	+99	+189	+187	+149	+123	+54	+21	+3	−31	−18	−4	+3	+14	+26	+16	+5	−11	−33	−77	−151	−181	−221
1868–79	+209	+246	+230	+151	+15	−87	−142	−132	−110	−67	−64	−91	−46	−6	+24	+41	−38	−103	−99	−19	−22	+26	+60	+81
12 years' mean	+78	+102	+136	+128	+62	+19	−24	−60	−93	−112	−139	−114	−36	+32	+87	+92	+30	−38	−54	−44	−30	+1	+5	+4

32. The sun-spot inequality with period =24·011 days is represented in Fig IV., and the Toronto temperature range inequality with period =24·022 days is represented in Fig. V. of the diagram which accompanies this Appendix.

It will be noticed that there is a very considerable resemblance between the corresponding sun-spot and temperature curves; the latter lagging somewhat behind the former.

Another point worthy of remark is the small range (as compared with that of sun-spots) of the temperature inequalities. This may, perhaps, be viewed in connexion with the well-known fact that the proportional terrestrial variations which accompany or follow variations in sun-spots between years of maximum and minimum are much smaller than the proportional variations in the spots themselves.

It will likewise be noticed that in the three consecutive series of 12 yearly temperature inequalities there are considerable signs of repetition, although this is not so marked as in the corresponding sun-spot numbers.

Let us now apply General Strachey's test to these 12 yearly series precisely in the way in which we previously applied it to the sun-spot series of four years.

By its means we find that, by assuming the supposed law of variation, the mean difference is proportionally reduced from 1 to 0·56 in the case of the sun-spot inequality at $+\frac{2}{12}$, while for the corresponding temperature inequality at $+\frac{1}{12}$, it is only reduced from 1 to 0·84.

33. Let us next obtain in detail particulars of the region round about $+\frac{60}{12}$. We get the following result:—

Table XIV.—Exhibiting in detail the region on either side of $+\frac{60}{12}$.

Period.	Magnitude.	Period.	Magnitude.
$+\frac{43}{12}$	2178	$\frac{61}{12}$	6800
$+\frac{44}{12}$	2658	$\frac{62}{12}$	6682
$+\frac{45}{12}$	3546	$\frac{63}{12}$	6458
$+\frac{46}{12}$	4228	$\frac{64}{12}$	6146
$+\frac{47}{12}$	4734	$\frac{65}{12}$	6322
$+\frac{48}{12}$	4656	$\frac{66}{12}$	5940
$+\frac{49}{12}$	4240	$\frac{67}{12}$	5208
$+\frac{50}{12}$	2672	$\frac{68}{12}$	4166
$+\frac{51}{12}$	2788	$\frac{69}{12}$	3202
$+\frac{52}{12}$	2474	$\frac{70}{12}$	2736
$+\frac{53}{12}$	4250	$\frac{71}{12}$	3586
$+\frac{54}{12}$	3160	$\frac{72}{12}$	4252
$+\frac{55}{12}$	1740	$\frac{73}{12}$	4114
$+\frac{56}{12}$	2580	$\frac{74}{12}$	4714
$+\frac{57}{12}$	2880	$\frac{75}{12}$	4606
$+\frac{58}{12}$	2542	$\frac{76}{12}$	4890
$+\frac{59}{12}$	3724	$\frac{77}{12}$	5116
$+\frac{60}{12}$	5582	$\frac{78}{12}$	5068

34. We see from this table that there are evidences of well marked inequalities at $+\frac{47}{12}$, $+\frac{53}{12}$, $+\frac{61}{12}$.

Let us select that at $+\frac{61}{12}$, and eliminate from it the effect of the others noted above in the same way as described in Art. 29. When this has been done we obtain the following result —

Period.	Corrected Magnitude.
$+\frac{60}{12}$ -	- 5973
$+\frac{61}{12}$ -	- 7019
$+\frac{62}{12}$ -	- 6677

It thus appears that the position of the inequality is not altered. We may compare this inequality with the sun-spot inequality which showed itself at $+\frac{60}{12}$ or between $+\frac{60}{12}$ and $+\frac{61}{12}$. This comparison is made in the following table.—

Table XV.—Comparing together the Sun-spot Inequality at $+\frac{60}{12}$ and the Temperature Range Inequality at $+\frac{61}{12}$.

$+\frac{60}{12}=24{\cdot}329$ days (Sun-spots).

1832–43 -	+22	+120	+196	−219	−442	−539	−709	−559	−690	−1036	−1294	−703	−130	+27	−451	−155	+381	+1062	+1036	+1051	+1033	+872	+495	+206
1844–55 -	+411	+637	+356	+544	−161	−788	−857	−889	−1188	−1344	−622	−339	−274	+16	+148	−1	+297	+707	+602	+408	+411	+628	+635	+544
1856–67 -	+462	+430	−153	−98	+52	−147	−448	−525	−529	−563	−570	−573	−381	−734	−186	+11	+867	+578	+411	+432	+627	+130	+105	+382
12 years' mean.	+298	+496	+143	+76	−184	−488	−671	−658	−802	−981	−829	−538	−262	−230	−163	−48	+516	+882	+693	+630	+690	+543	+412	+377

$+\frac{61}{12}=24{\cdot}334$ days (Toronto Temperature Range).

1844–55 -	−96	−43	+34	+93	+104	+82	+7	−112	−227	−257	−236	−106	+64	+141	+221	+177	+80	+63	+10	+39	+61	+9	−38	−95
1856–67 -	−197	−210	−154	−14	+150	+200	+140	−2	−154	−240	−299	−262	−187	−51	+119	+189	+243	+229	+171	+168	+126	+71	+19	−103
1868–79 -	+44	+95	+103	+159	+191	+143	+71	−27	−139	−205	−220	−216	−148	−58	−42	−30	−25	−5	+39	+75	+61	+29	+47	+43
12 years' mean.	−83	−53	−6	+79	+148	+142	+73	−47	−173	−234	−252	−195	−90	+11	+99	+112	+99	+96	+73	+94	+83	+37	+9	−52

35. The mean sun-spot and temperature inequalities having periods of 24·329 and 24·334 days are represented in Figs. VI. and VII. of the diagram which accompanies this Appendix.

It will be noticed that there is a very considerable resemblance between these two curves; the latter probably lagging slightly behind the former We have to repeat the observation made in Art 32 regarding the comparative smallness of the range of the temperature inequality as compared with that of sun-spots.

It will likewise be noticed that in the three consecutive series of twelve-year temperature inequalities there are considerable signs of repetition, although this is not so marked as in the corresponding sun-spot numbers.

Let us now apply General Strachey's test to these series in the same way in which it was applied in Art. 32. By its means we find that, assuming the supposed law of variation, the mean difference is proportionally reduced from 1 to 0 38 in the case of the sun-spot inequality, while for the corresponding temperature inequality it is only reduced from 1 to 0·54.

36. In the course of this paper I have given evidence which tends to show that there are in all probability solar variations of short period, and that these are connected with variations of temperature range. Toronto was chosen as a station from which accurate information with regard to temperature was to be obtained, and also as one which, being in America, may be supposed to be influenced more directly and immediately by solar changes than an equally good station in Europe

Nevertheless, Toronto is not the only station from which we may obtain results exhibiting relations between atmospheric temperature and solar changes. And in a paper communicated to the Royal Society on November 20, 1879, it is shown that we have traces of an inequality having a period very near 24 days in the temperature range of Kew and Utrecht, as well as in the magnetic declination range of Kew, Prague, and Trevandrum. In fine, this inequality appears wherever it has been sought for. In the same paper evidence has been adduced to show that the phase of a given meteorological inequality is not the same at the various stations, but that the maximum or any other salient point reaches Kew about eight days after it has appeared in Toronto and Utrecht about a day and a half after it has appeared in Kew. A similar progress from west to east, but only quicker, is suspected in the case of what may be termed magnetic weather

37. It becomes a point of interest, therefore, to ascertain with as much accuracy as possible the relations as regards phase between solar inequalities and corresponding temperature range inequalities at Toronto. We wish to know whether the latter lag behind the former, and if so, to what extent? This may be ascertained in the following manner. Any one of the numbers in Table VI. is the sum of the 24 terms of an inequality which have been added together without respect of sign. Thus the number corresponding to 0 0 or 24·00 days is 26,390; and there are 29 such numbers in all, extending from −7 0 to +7·0.

During the investigation a similar table was prepared for the Toronto temperature range, but it was thought unnecessary to give this table in the text. This table like the former consists of 29 numbers, extending from −7 0 to +7·0, each of which represents the sum of the 24 terms of an inequality added together without respect of sign.

There are 24 years of observations common to both these tables and in what follows we shall confine ourselves to these 24 years. They are the years from 1844 to 1867 inclusive

It has been remarked in Art 32 that the range of the solar inequalities is much greater than that of the temperature inequalities; and I have found that in order to reduce both sets to nearly the same range it will be necessary to divide each term of each solar inequality by 3 655 Let us perform this division for the various 24 years' solar inequalities which we now wish to compare with the corresponding 24 years' temperature range inequalities We thus give both sets very nearly the same range.

38 We have next to decide whether the various phases of these inequalities prepared for comparison in the above manner occur in the sun before they occur in Toronto, and if so, how long before?

This may be ascertained in the following manner. If we add together algebraically as they stand a solar inequality and a corresponding Toronto inequality, say for instance, the one at 0·0, it does not follow that we shall obtain an inequality the sum of whose terms shall be equal to the sum of the 48 numbers added together without respect of sign. For the two inequalities even if precisely the same in type, may not have their corresponding phases occurring together. The signs of the numbers which we add together algebraically may therefore sometimes be different, and we shall then have to subtract the one from the other

It thus appears that if there be a want of simultaneity of phase in two such inequalities, the algebraic addition together of the two will give a result less than the sum (without reference to signs) of the 48 terms. And this falling off will be greater the greater the want of correspondence in phase.

Let us now add together algebraically the various solar inequalities (29 in all) each with the corresponding Toronto inequality, under the supposition that the phases are simultaneous in the sun and at Toronto We thus get a series of 29 inequalities representing the united result of the two. Let us then add together the various numbers of this series Let us next, on the supposition that a solar phase occurs three days before a corresponding one at Toronto, rectify this by pushing each Toronto inequality three divisions to the left before adding it to the corresponding solar inequality. We obtain by this means as before a series of 29 inequalities. Let us then add together the various numbers of this series.

39. In the following table we have exhibited the results obtained by this method of treatment.

TABLE XVI.

Algebraic sum of Solar and Toronto Inequalities:—

Sun and Toronto (together) - - -	=179285
Sun and (Toronto pushed 1 division to left) -	=186257
Sun and (Toronto pushed 2 divisions to left) -	=182402
Sun and (Toronto pushed 3 divisions to left) -	=181714
Sun and (Toronto pushed 4 divisions to left) -	=179447
Sun and (Toronto pushed 5 divisions to left) -	=178920

It thus appears that we get the greatest sum, and consequently the nearest approach to similarity of phase, when we push Toronto to the left between one and two divisions. In other words,

Toronto phases lag behind similar solar phases between one and two days.

40. One remark before concluding. The evidence herein given tends not only to show that solar variations of short period exist, but to render it possible if not probable that they are the causes of temperature range periods of similar length in such a way that a maximum amount of spots corresponds to a maximum and not to a minimum temperature range, or in other words, denotes in all probability an accession of solar energy and not a diminution thereof.

If it be said that such evidence is not yet absolutely conclusive, it may be replied that the aim of the writer has solely been to introduce this subject as one upon which labour and thought may advantageously be expended.

It is because the subject is *not* finally settled that such labour and thought are particularly called for. And the writer will be satisfied if it be acknowledged that we have here a hopeful opening for investigation, whether we regard the subject as one of scientific interest or as one of possible practical importance.

In conclusion, the writer desires to acknowledge with thanks the assistance he has derived from Mr. Dodgson in the compilation and revision of this paper.

APPENDIX II.

PAPERS CONNECTED WITH THE MEASUREMENT OF SOLAR RADIATION.

Description of an Instrument for measuring possible Variations in the Sun's direct Heat. By Professor Balfour Stewart.*

Notwithstanding all that has been done in Solar Physics, we have as yet no definite and direct information on the fundamental question of the variability of the sun's heat. We are aware of the existence of certain changes in the appearance of the solar disc, which are approximately periodical, and we have some reason for believing that these changes indicate most probably the combined results of several long period inequalities on the one hand, and of several short period inequalities on the other; but we are not at present in a condition to tell from direct observations with an actinometer whether a large amount of sun spots is accompanied by an increase or by a diminution in the sun's direct heat, or, indeed, whether sun spots have any perceptible accompaniment of this kind. There are two difficulties in the way of our obtaining this information.

The one is caused by the variability in the constituents of the earth's atmosphere, which form, as it were, a blind or medium of ever varying opacity, through which we are forced to view the sun. This source of uncertainty can never be entirely overcome, but it may be reduced to a minimum by our making our observations at appropriate stations of high elevation, and thereby removing the effect of the lower and grosser strata of the atmosphere.

* A description of this instrument first appeared in the Proceedings of the Manchester Literary and Philosophical Society, Session 1875-76.

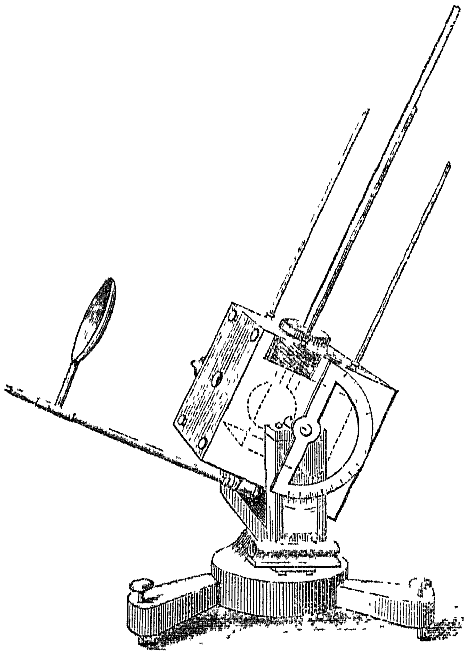
The other difficulty is of an instrumental nature Actinometers, or instruments for measuring the sun's direct heat, are made use of in the following manner:—

In the first place the instrument is sheltered from the sun, but exposed to the clear sky, say for five minutes Let the heat so lost be termed r *Secondly*, the instrument is turned to the sun for five minutes Let the heat so gained be termed R. *Thirdly*, the instrument, being now hotter than it was in the first operation, is turned once more so as to be exposed to the clear sky for five minutes while it is shielded from the sun. Let the heat so lost be termed r'.

It thus appears that r denotes the heat lost by convection and radiation united when the instrument, before being heated by the sun, is exposed for five minutes to the clear sky, while r' denotes the heat lost by these same two operations by a similar exposure after the instrument has been heated by the sun; and it is assumed that the heat lost from these two causes during the time when the instrument is being heated by the sun will be a mean between r and r', and hence that the whole effect of the sun's rays will be in reality $R + \frac{r+r'}{2}$.

Now, although this assumption may, in the average of a great number of observations represent the truth, yet in many individual cases it may be far from being true It would therefore seem to be desirable to get rid of this uncertainty by constructing an instrument in which we are sure that these causes of variability are reduced to a minimum.

This has been attempted in the instrument a sketch of which accompanies the present description.



It consists of a large mercurial thermometer with its bulb in the middle of a cubical chamber of brass, this chamber being so massive that its temperature will remain sensibly constant for some time (the bulb is denoted by dotted lines in the sketch). The chamber with its thermometer has a motion in azimuth round a vertical axis, and also a motion in altitude round a horizontal axis.

A lens of suitable aperture (which may be varied by diaphragms), and also of appropriate focal length, is attached by means of a rod to the cubical chamber, so as to move with it. Thus the whole instrument may be easily moved into such a position that the lens, as well as the upper side of the chamber (which is parallel to the plane of the lens), may face the sun, and an image of the sun be thrown through a hole in the side of the chamber upon the thermometer bulb. This hole is covered or uncovered by means of a slide. Of course this hole is only uncovered when an observation is being made. The stem of the thermometer protrudes from the chamber as in the figure. A screw, somewhat larger in diameter than the bulb of the thermometer, is made use of in order to attach the thermometer to its enclosure; and a smaller screw, pressing home upon india-rubber washers, enables the thermometer to be properly adjusted, and kept tight when in adjustment.

The stem is about 18 inches long, and about five degrees go to the inch, thus the scale is very open. The stem is protected from the risk of accident by an appropriate shield.[1] By means of a stem of this length it is probable that sufficient range will be secured to provide for observations all the year round at most stations. It may, however, happen that in certain localities the summer temperature is very high and the winter temperature very low. In such a case it will be desirable to have two thermometers, one for winter and one for summer use; the scale of the one overlapping that of the other to some extent.

The massive brass chamber is lined with a covering of felt, and this again is surrounded by polished brass plates. By this means the heat of the sun will be to a great extent reflected off, and that which is absorbed having to pass through the felt, which is a bad conductor, will only be able to raise with extreme slowness the temperature of the massive brass chamber within.

In such an instrument, therefore, r and r' will be very small, and we may be quite certain that $R + \frac{r + r'}{2}$ will accurately represent the heating effect of the sun.

We may probably suppose that in the same instrument the lens will always stop the same, or nearly the same, proportion of the solar rays. But the lens of one instrument may not stop the same proportion as that of another instrument. It must, however, be borne in mind that the instrument is a differential one, and that all such actinometers before being used should, if possible, be compared with the standard at South Kensington, and thus have their coefficients determined.

The sketch now given exhibits an improvement introduced by General Strachey consisting of a graduated arc, by which the sun's altitude during an observation can be read off with a sufficient amount of accuracy. General Strachey has since introduced screws,

[1] This shield is exhibited in the figure broken off so as not to occupy too much space.

by means of which slow motion either in altitude or in azimuth, may be given to the instrument; but these are not exhibited in the above sketch.

This description is accompanied by three memoranda, of which A and B refer to the method of adjusting the instrument and observing with it, while C embodies certain suggestions of the Solar Physics Committee regarding the best method of utilizing the observations.

(A.)

Memorandum by Professor Balfour Stewart.

The object of this instrument being to give us the relative value of the sun's direct heat from day to day and from year to year, it is necessary that all its parts susceptible of alteration should remain in a constant state, and that the observations with it should be made in a uniform manner

This will involve constancy (1) of the lens with its adjustments; (2) of the method of exposure; (3) of the thermometer and its adjustments; (4) of the method of observing with the instrument.

(1.) *The Lens with its adjustments.*

The lens is provided with several diaphragms. It should first be ascertained which of the diaphragms is most suitable to the average power of the sun at the place of observation If we take three minutes as a good time of exposure the sun should heat up the thermometer not more than three degrees or so during this time Having once selected a diaphragm the same one should invariably be used Care should be taken to see that the glass of the lens is quite clean and not coated with the slightest film of moisture or dirt

The lens should be placed at such a distance along its rod that the focus or small image of the sun should fall not further from the bulb of the thermometer than the slit of the aperture. Generally speaking the image would naturally be formed on this slit, but in some instruments it might be desirable to have it a trifle nearer the bulb in order that the rays after they diverge again should be all well caught on the bulb of the thermometer It is of essential importance that all the rays should be so caught.

Having ascertained the best distance for the lens care should be taken that the lens is always kept at this distance and in a central position.

(2.) *The method of exposure.*

Exposure is accomplished by means of a slide, which when withdrawn uncovers a circular aperture through which the beam may fall upon the bulb of a thermometer.

Care should be taken that this slides easily as well as truly.

On the outside of the slide there is a small circular mark which, when the slide is in its place, is symmetrically above the circular aperture. This mark is decidedly larger than the sun's image When exposure is about to be made the sun's image should just be entirely within this circle at that side from which the sun carries it by his diurnal motion. Thus during the time of exposure the image will be travelling further within this circle. There can be no harm in ascertaining by experiment that the sun during the time of ex-

posure never travels so far as to bring the image out of this circle. In order that the brightness of the image should not affect the eye of the observer, this circle may be blackened if thought necessary.

Care must be taken that at the moment of making exposure by withdrawing the slide the instrument is not shaken so as to alter its position The circular aperture is conical and opens out towards the bulb. There is thus no danger that any ray of light which passes the aperture should strike against the sides. Moreover these sides are blackened.

(3) *The Thermometer and its adjustments*

The same thermometer should alway, if possible, be used, and in order to prevent accidents it should, if possible, always be kept in position

The bulb of the thermometer has a pointed termination, and perhaps the best plan is to make this pointed glass termination always lightly touch the side of the chamber, provided that this seems a reasonably good position for the thermometer bulb with reference to the hole.

This regulation will secure the position of the thermometer in one direction, but it is likewise desirable that there should be no turning round of the stem from one observation to another. Perhaps this will be best accomplished by making a small mark on the stem which should always be kept uppermost.

The stem of the thermometer should be tied centrally into the frame at the top so as to prevent its being bent or strained by its own weight.

Under ordinary circumstances it is not probable that the glass of the thermometer bulb should get coated with moisture or dirt, but in certain contingencies of climate it is perhaps advisable to ascertain this point. This can be done by removing the top which contains the slide and without disturbing the adjustments of the thermometer.

The thermometer will probably be graduated into degrees and fifths of a degree. To prevent the possibility of error, the observer might record his observation thus:—

Nearest degree.	Divisions and decimals of a division above degree.	True reading.
60	3·2	60·64
73	1·8	73·36

The observer should read the thermometer with a magnifying lens, placing his eye so as to prevent parallax. For this purpose let him take that graduation which is nearest the extremity of the mercurial column and place his eye so that the reflexion of this graduation from the surface of the mercurial column beneath it coincides with the graduation itself. Let him then take his reading.

It is proper to observe that the thermometer will read somewhat differently for the same temperature according to the inclination or slope of the instrument. This, however, is not a point of practical importance since the observations are differential, while during one complete observation the thermometer always preserves the same inclination.

(4.) *Method of observing.*

The instrument should be in position for some short time, say quarter of an hour, before observations are begun. Its outside

should be kept polished. Let us suppose that the time of exposure is two minutes. The observer should—

(*a*) Read thermometer exactly two minutes before exposure begins.

(*b*) The sun's image being just within the circle marked on the slide and the instrument ready for exposure a reading (*b*) should be taken exactly two minutes after (*a*) and exposure should at once be made

(*c*) Exactly two minutes after (*b*) the exposure should be discontinued and a reading made.

(*d*) Another reading (*d*) should be made two minutes after (*c*).

This is all that is necessary for a single set of observations, but a double set is very desirable In this case when (*d*) is made the instrument should be again exposed for two minutes and an observation (*e*) made at the moment when this exposure is discontinued And finally another observation (*f*) should be made two minutes after (*e*) A good chronometer beating seconds or half seconds is essential to such observations. The following is an example of a set of observations taken at Manchester with one of these instruments

Time	State of instrument.	Reading in degrees Fahr.	
1 30	not exposed	54·10	(*a*)
32	exposure begun	54·16	(*b*)
34	exposure stopped	57·60	(*c*)
36	second exposure begun	57·28	(*d*)
38	,, ,, stopped	60 44	(*e*)
40	not exposed	59·74	(*f*)

It thus appears that for the first two minutes before exposure there was a rise $= \cdot 06$. During two minutes exposure there was a rise $= 3\cdot 44$. During two minutes after exposure there was a fall $= \cdot 32$. According to the well known formula $3\ 44 + \frac{\cdot 32 - \cdot 06}{2} = 3\cdot 57$ will be the value of the sun's heat derived from the first series of observations. From the second series we have for two minutes before exposure a fall $= \cdot 32$ During exposure a rise $= 3\cdot 16$. For two minutes after exposure a fall $= \cdot 70$. Hence according to this series $3\cdot 16 + \frac{\cdot 70 + \cdot 32}{2} = 3\cdot 67$ will be the valve of the sun's heat.

It thus appears that the results of the two series agree very well together.

In the more perfect form of instrument a circle gives the sun's altitude which should be recorded at the beginning and the end of each set of observations.

(B.)

Memorandum by Lieut.-General Strachey

As it was thought likely that difficulties might arise in the determination of the true local time of observation, an addition has been made to the instrument as originally designed, by which the actual altitude or zenith distance of the sun may be observed simultaneously with the thermometer readings.

A graduated arc has been fixed to the thermometer frame by which the sun's altitude can be read off to quarter degrees, an

amount of accuracy which is sufficient for the object. Three arms with levelling screws are formed on the stand of the instrument by which the vertical axis is brought into a truly vertical position previous to use.

To test the readings of altitude it will suffice, after properly levelling the instrument, to bring the zero of the graduated arc to the zero on the fixed vernier, and then to ascertain whether the line drawn from the centre of the lens to the centre of the aperture within which the focus of the lens falls, is truly vertical. That is known by fixing a small plummet (which is supplied) to the centre of a cap which fits over the lens and observing whether the point of the brass bob coincides with the cross lines cut on the sliding screen which closes the aperture opening to the thermometer bulb If the coincidence is satisfactory no correction will be needed, otherwise, the instrument should be turned on its horizontal axis till the plummet covers the point of intersection of the cross lines, and the reading on the arc will be the error to be applied as a correction with its proper sign If the observer so prefers, and has the needful skill and appliances, he can shift the vernier and thus re-adjust the zero reading

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MEMORANDUM for the USE of OBSERVERS with PROFESSOR BALFOUR STEWART'S ACTINOMETER, prepared by PROFESSOR G G. STOKES, Sec R.S., and adopted by the COMMITTEE ON SOLAR PHYSICS.

The Committee regard the instrument herein described as an apparently good instrument, though it has not yet been tried under conditions more favourable to actinometric observation than can be obtained in the United Kingdom. Partly on this account, but even more on account of the still immature condition of the whole subject of actinometry, they deem it premature to attempt to draw out anything like a code of instructions for regular observation with it, and think it best to place the instrument in the hands of one or more intelligent observers interested in the subject, and residing in suitable localities at very considerable elevations above the level of the sea, indicating to them the objects which it is sought to attain, but leaving it in great measure to their own judgment, and to the experience they will gain in using the instrument, how best to carry out the observations in detail.

Let it be understood then that the chief object which it is sought *ultimately* to attain by the use of an actinometer is a knowledge of the variations (if any) in the heat radiation from the sun itself.

The first great obstacle to the attainment of this object is that arising from variations in the heat-intercepting power of the earth's atmosphere. To reduce this to a minimum a station is in the first instance chosen which, while favourably conditioned in other respects as regards climate, is well elevated above the level of the sea, so as to get rid of the denser and more dusty and hazy portions of the atmosphere. A suitable station having been chosen, the next point is to select proper occasions for observation. A cloud covering the sun would of course make the observation impossible; but even a slight veil of cirrus is found to interfere materially with the amount of heat coming directly (that is, without any deflection) from the sun. Hence the observer should choose times when the blue sky is to all appearance free from haze. Detached clouds need not prevent an observation, unless during some part of the time of exposure they

come so near the sun that the rays they reflect are liable to pass through the lens in such a direction as to fall on the bulb of the thermometer.

Vitiation of the observation by *visible* causes of interception of the heat rays having been thus guarded against, there still remains the possibility of casual fluctuations being produced by the invisible constituents of the atmosphere. For the detection of these, and for learning the conditions of their absence, we can only have recourse to a comparison of the results of observations made on different occasions To render such a comparison effective, memoranda should be made at the time of the observations of the condition of the atmosphere, so far as can be judged by the eye, and by readings of the ordinary meteorological instruments, and the altitude of the sun should be measured (no great accuracy being required in the measures) and recorded, or else subsequently calculated from the known time of day and year.

With a view to throwing light on the conditions of atmospheric fluctuations in the radiation received at the surface of the earth, the Committee would suggest that the actinometer above described should be observed in conjunction with some qualitative instrument which gives an immediate graphical and visible indication of the power of the sun. An instrument devised by Mr. Winstanley, and modified by Captain Abney, would appear to be very suitable for this purpose A complete accordance between the two instruments is not to be expected, because the thermometer in Mr Winstanley's instrument is exposed to radiation from various directions. The difference between the two instruments in this respect may be useful in throwing light on the causes of atmospheric fluctuation.

When the observer has learned how to avoid at least the grosser forms of atmospheric fluctuation, he may attack the problem of the effect of the sun's altitude on the amount of heat radiation intercepted. For this purpose specially favourable days should be chosen, and observations made at frequent intervals, from shortly after sunrise to near sunset. The condition of the atmosphere on these days should be carefully recorded. The days used for the purpose should not be confined to one season, as it is possible that the normal condition of the atmosphere at a given place, and with it the amount of absorption for a given altitude of the sun, may vary with the season All through the observations above referred to, or at least after he has learned to recognise and avoid the more serious atmospheric fluctuations, the observer must bear in mind that the instrument itself (the actinometer) is on its trial, and he must be alive to the possibility of variations in the readings, due merely to different conditions of exposure, or to other purely instrumental sources For testing the instrument itself, times should be chosen when, as far as the observer can judge, there is a freedom from casual atmospheric fluctuations, and it would be well to take a good number of consecutive observations with the screen alternately on and off.

When the observer has learned how to avoid, as far as may be, merely casual atmospheric fluctuations, and considers that the instrument has been sufficiently tested, he may commence observations taken with a view to their possibly forming part of a permanent record. For this it would be proper to get a result for each day, so so far as atmospheric conditions permit; but how many observations it would be desirable to take, whether they should be taken at stated hours, or with stated altitudes of the sun, or whether the most favourable opportunities as to atmospheric conditions should

be seized which present themselves, not too far from noon, so that the sun has a high altitude, are questions which cannot well be answered till the preliminary experiments above mentioned have been made The observations for permanent record can hardly be *reduced* until the effect of altitude has been determined, but they may be *made* as soon as the observer has made sufficient progress in learning to avoid casual sources of error.

When all has been done that can be done at one station, the discussion of the records obtained may lead to presumptive evidence in favour of a variation in the actual radiation emitted by the sun itself, but so important a conclusion could not be considered as established without corroborative evidence, arising from the comparison of simultaneous observations at at least one other favourably situated station widely separated from the former. As soon, therefore, as the method shall have been brought into thorough working order, especially as regards the rules to be followed for the avoidance of casual atmospheric fluctuations, it is desirable that the stations of observation should be multiplied.

APPENDIX I.

Description of Roscoe's Actinometer, modified by Horace Darwin, and manufactured by the Cambridge Scientific Instrument Company.

April 11, 1881.

The measurement of the chemical effect of total daylight is made in this instrument according to Roscoe's method by exposing a piece of sensitised paper to the light for known intervals of time at each hour. To effect this the piece of sensitised paper is fixed round a drum. This drum can turn on a horizontal axis, and the frame which supports it can slide horizontally. A piece of thin sheet brass is fixed over the drum and a hole is cut through it. It is so arranged that it presses down lightly on the top of the drum, thus a small piece of the sensitised paper is always exposed to the daylight, and the rest of the paper is in total darkness. Thus by the horizontal movement of the frame and the turning of the drum every part of the sensitised paper can be brought under the hole. We will suppose the instrument to be working. The frame which supports the drum has a slow and continuous movement in a horizontal direction. Between the hours the drum does not turn, and it only moves slightly in a horizontal direction. At the hour the drum turns suddenly for a small part of a revolution, thus exposing a fresh piece of paper under the hole. After 2 seconds it again turns suddenly as before, exposing that piece of paper for 2 seconds. Similarly fresh pieces of paper are exposed for 2, 4, 6, 10, 20, 40, 90 seconds, and after this the drum does not rotate again till the next hour, when a similar set of movements takes place. Hence, between the hours there is a piece of paper exposed for 57 minutes, and which is useless on account of the long exposure. Owing to the horizontal movement of the drum a fresh piece of paper is exposed when one complete revolution of the drum has taken place.

The mechanism by which this movement is effected is as follows:

To the barrel of a clock (*i.e.*, the barrel round which the gut from the weight is coiled and which drives the clock) a pinion is fixed. This pinion gears into a tooth wheel, and on the arbor of this wheel

a small barrel is fixed. When the clock is wound up this small barrel turns, and in so doing winds a piece of chain on it, and as the weight of the clock goes down this small drum turns slowly in the opposite direction, and the chain is slowly unwound from it. The other end of this chain is fixed to the frame which supports the drum, and which can slide horizontally Thus if the chain is always kept taut, the drum will slowly move horizontally in one direction as the clock goes, and when the clock is wound up it will be pulled back into its original position. This chain is kept taut by a piece of gut, which is fastened to the other end of the frame, and thence passes over a pulley and is attached to a weight. The horizontal movement of the drum is thus given, and it only remains to explain the arrangement for the rotatory movement

See Fig. I. A is an arbor which has a tendency to turn in the direction of the arrow. The mechanism for doing this is not shown in the sketch, but is arranged thus · On the arbor is a pinion into which a wheel gears; this wheel is made to turn by means of a weight attached to a string which is wound round a small barrel fixed to the same arbor as the wheel. B is a ratchet wheel, which is not fixed to the arbor A, but turns freely on it in the direction of the arrow once in 3 minutes, by being geared to a wheel on the scape wheel arbor of the clock. This gearing is not shown in order not to complicate the sketch. An arm C is fixed to the arbor A. D is a pin fixed to the end of this arm, on this pin a piece E can turn, a pin F projects from the side of the piece E, and is so arranged that it can engage in the teeth of the rachet wheel B. A spring G tends to turn the piece E, so that if not prevented the pin F will be forced down between the teeth of the ratchet wheel. We have seen that the Arbor A tends to turn and carry the arm C with it, in the position shown in the sketch this turning is prevented by the hooked end H of the lever HK, this hook catches in the end of the piece E, and as the other end of this piece comes against a stop L the arm C is held in the position shown in the sketch, this stop is fixed to the arm C and projects from its side. In this position the pin F does not engage in the teeth of the rachet wheel B. The weight tending to turn the arbor A will keep the arm in this position. At the hour the hook H is raised, thus releasing the piece E, the spring G will then turn the piece E, so that the pin F will engage in the teeth of the rachet wheel. We have seen that the rachet wheel is always turning at the rate of one turn in 3 minutes, and as the arbor A tends to turn in the same direction it will now turn at the same rate. Before the arm C has time to get round again to its original position the hook H has come down again, and thus the outer end of the piece E will hit against it, but the arm will go on for a short time till the other end of the piece E comes against the stop L. This movement throws the pin F out of gear with the rachet wheel and again holds the arbor A Thus at each hour the arbor A takes one complete revolution in 3 minutes, and then remains at rest till the next hour, and so on. The manner in which this regulates the turning of the drum will be explained further on. The lever HK can turn about its centre, and its end K rests on the edge of the disc M This disc turns once an hour, and has a nick cut in its edge so that at the hour the end K falls into the nick and thus the end H is raised. The slanting side of the nick again raises K, and so lowers H before the end of the 3 minutes, at the end of which time the arm C returns to its original position; the disc M is divided into 60 divisions, and can be set like the hands of a clock, *i e*, it can turn with a stiff joint on the hour arbor; thus it can be set so that the nick will come uppermost exactly at each hour.

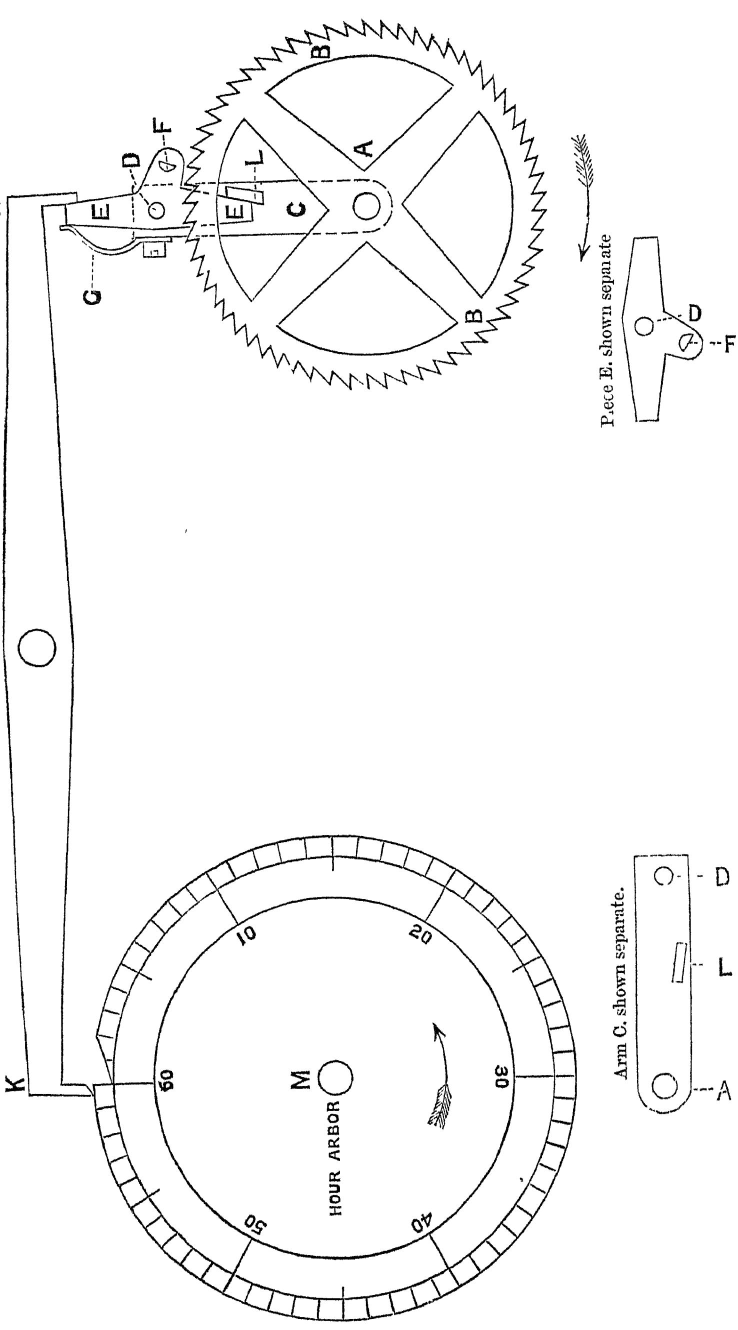
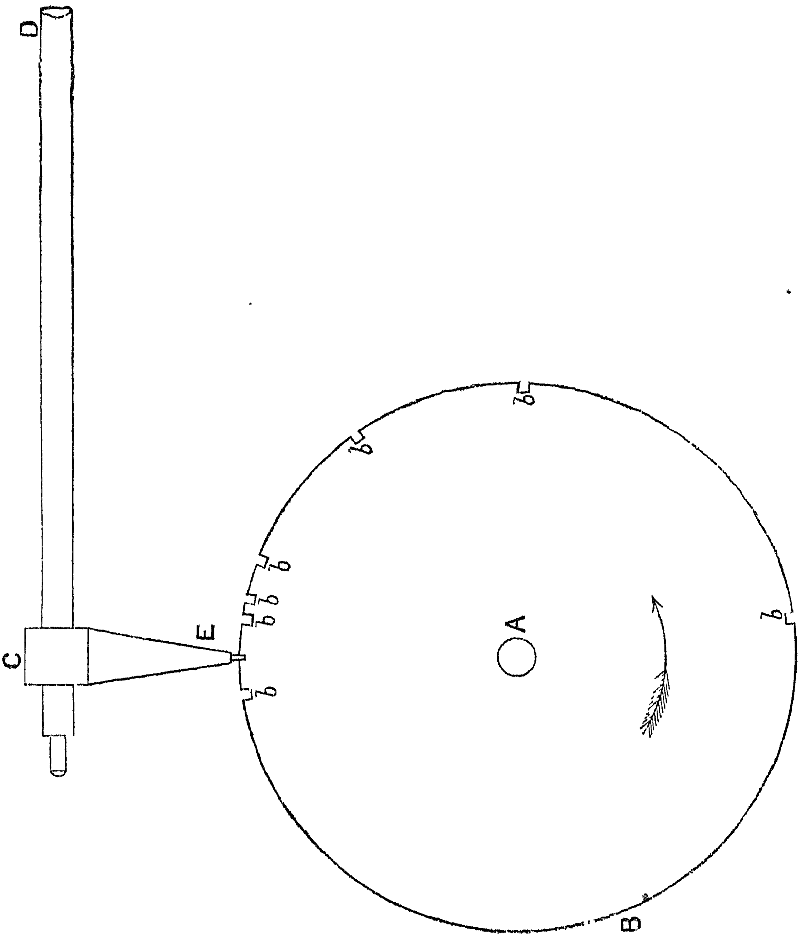

H
K
E
D
F
G
L
C
A
B
B
M
HOUR ARBOR
10
20
30
40
50
60
Piece E. shown separate
D
F
Arm C. shown separate.
D
L
A

Fig. I.

Fig. II.



In Fig. II A represents the same arbor as A in Fig. I, but a separate sketch is given in order to make them more clear. A disc B is fixed to the arbor. Thus at each hour this disc makes one complete revolution in three minutes On the axis of the drum to which the paper is fixed there is a small barrel, round which a cord is wound and a weight attached to the cord. Thus the drum tends to turn. This barrel is connected by a train of wheels with the arbor CD, which thus also tends to turn. For one turn of this arbor the drum turns through the right amount to expose a fresh piece of paper. Fixed to this arbor is a small arm CE The point of this arm is made small, and rests against the side of the disc. At varying intervals round the disc nicks *bb* are cut through its edge. The point of the arm CE is made so as to pass through these nicks. During the hour this point rests against the side of the disc between two nicks. When at the hour this disc turns, every time a nick comes opposite the point of the arm, the arbor CD gives one turn, and thus the drum turns through a fraction of a revolution, and a fresh piece of paper is exposed. This disc turns with jerks at each second as the clock ticks; the point E passes through a nick during one of these jerks while the disc is moving comparatively quickly. Thus the intermittent movement of the drum takes places with considerable accuracy. Any required lengths of exposure can be given by putting the nicks in the corresponding places The nicks are cut diagonally across the edge of the disc. This is done in order to prevent the possibility of the points E coming round so quickly as to pass through the same nick twice.

The accompanying sketches must be taken to be merely as diagrams to show the principle of the mechanism

The above instrument is analogous in principle to that described by Professor Roscoe in the Philosophical Transactions for 1871, a modified form of which has now been continuously at work at South Kensington for several months.

Mr. Horace Darwin's arrangement is in several particulars superior to the original form of Roscoe's actinometer, and especially in requiring a smaller quantity of the sensitised paper It has been tested by Prof. Roscoe and found to work perfectly The instrument is now set up at South Kensington, and gives regular and reliable results.

A special reading-off apparatus has been designed by Captain Abney, which greatly facilitates the readings, and renders the daily operations as simple and rapid as possible.

APPENDIX K.

EXTRACT FROM A LETTER, DATED 8TH APRIL 1881, FROM MR. HENRY F. BLANFORD, METEOROLOGICAL REPORTER TO THE GOVERNMENT OF INDIA, TO PROFESSOR STOKES, SECRETARY R S.

I am now despatching to you the results of a year's observations with Balfour Stewart's actinometer at the Alipore Observatory. They have been taken entirely by the native observers, but I do not think there is any reason to doubt that they have been taken carefully and in accordance with the instructions given them except in one point, which they misapprehended This was in adhering to the

practice of taking shade observations at a half minute interval. Except as regards the final noon shade observation, this half minute interval is merely a superfluity, but the second sun observation at noon is rendered imperfect by the want of the final two minutes' shade observation

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MEMORANDUM to accompany the actinometric observations made with a Balfour Stewart's actinometer at the Alipore Observatory, Calcutta, from April 1880 to March 1881

From the 10th April 1880 to the 28th February 1881 the practice has been as follows.—

The observations were taken as follows:—At two hours three minutes before apparent noon, the instrument being in position with the screen shut, a first reading was taken. After remaining two minutes by chronometer with screen shut, a second reading was taken and the screen withdrawn After two minutes exposure by chronometer, the screen was closed and the third reading taken at the same instant. A fourth reading was taken half a minute later, and a fifth two minutes after closing the screen. Hence the intervals were .

Shade 2 minutes		
Sun 2	,,	
Shade $\frac{1}{2}$	,,	2 minutes.
Shade $1\frac{1}{2}$	,,	

At 1 hour 57 minutes after apparent noon the series of observations were similar.

At five minutes before apparent noon the readings were taken at the following intervals.

Shade 2 minutes.		
Sun 2	,,	
Shade $\frac{1}{2}$	,,	2 minutes
Shade $1\frac{1}{2}$	,,	
Sun 2	,,	
Shade $\frac{1}{2}$	,,	

Through a misapprehension on the part of the observers the final shade observation at noon was not prolonged to two minutes (as it should have been). The consequence is that up to the end of February there is only one complete noon observation, which is that recorded in the accompanying table

From the 1st March 1881, the intervals of both sun and shade observations are in all cases two minutes There are thus after this date two complete noon observations, but it is only the first of these that is recorded in the following table

Before the 10th April 1880 no initial shade observation was taken, but in other respects the practice was the same as that above described.

The following Table is a record of Observations made with a Balfour Stewart's Actinometer at the Alipore Observatory, Calcutta, from April 1880 to March 1881

N B —The Table is preceded by the records of the Observations upon three days, May 21, Dec 16, and Dec 21, which have been selected at random, and have been given in full to show the mode of using the instrument

Explanation of Symbols

C Cirrus
Cs Cirro-stratus
Ck Cirro-cumulus
K Cumulus
Fk Fracto-cumulus

Date	Two hours before apparent noon					At apparent noon					Two hours after apparent noon				
	Readings	Change in ■	Change in ○	Reduced ○	Remarks	Readings	Change in ■	Change in ○	Reduced ○	Remarks	Readings	Change in ■	Change in ○	Reduced ○	Remarks
May 21					Cloudy	88 58				Scattered cirri	95 58				Scattered C and C
						88 50	+0 12			,,	95 62	+0 01			
						96 20		+7 70	+8 01	,,	102 66		+7 04	+7 33	
						96 00	−0 20			,,	102 52	−0 1[illegible]			
						95 46	−0 71			,,	102 01	−0 62			
						101 82		+6 36		,,					
						101 16	−0 3[illegible]			,,					
Dec 16	72 61				Pale sky	77 68				Sky pale	81 00				Sky pale
	72 76	+0 12			,,	77 80	+0 12				81 11	+0 11			
	80 [illegible]		+7 51	+7 65	,,	85 62		+7 82	+8 03		88 58		+7 21	+7 56	
	80 20	−0 10			,,	85 11	−0 18				88 20	−0 18			
	79 86	−0 31			,,	84 90	−0 51				87 60	−0 78			
						91 68		+6 78							
						91 30	−0 38								
21	67 82				Clear	72 52				Clear	76 20				Clear
	68 08	+0 26				72 60	+0 08				76 30	+0 10			
	76 08		+8 00	+8 19		81 11		+8 51	+8 9[illegible]		84 10		+7 80	+8 09	
	75 98	−0 10				80 94	−0 20				83 91	−0 10			
	75 11	−0 64				80 21	−0 90				83 12	−0 68			
						87 62		+7 3[illegible]							
						87 20	−0 42								

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx. temperature of air	Increase from direct solar radiation	Remarks	Approx. temperature of air	Increase from direct solar radiation	Remarks	Approx. temperature of air	Increase from direct solar radiation	Remarks
1880 Apr. 10	97 97	6.88	Clear	93 93	7.07	Slightly cloudy	92 92	6.92	Clear
„ 11	86 86	6.72	Do	92 92	7.19	Clear	95 93	6.90	Do
„ 12	96 96	6.61	Do	94 94	7.39	Sky pale	95 95	7.05	Do
„ 13	97 97	6.95	Do	94 94	6.87	Do	96 96	6.88	Do
„ 14	97 97	6.28	Do	95 94	7.31	Do	97 97	6.96	
„ 15			Cloudy	94 94	7.01	Thin patches of Ck hid the sun			Cloudy
„ 16			Do	94 94	7.51	Patches of K scattered all over the sky	93 93	6.99	
„ 17	92 93	6.92	Scattered cumuli						
„ 18	86 86	7.01	Sky pale	88 88	7.11	Sky pale			Do
„ 19	81 81	7.67	Scattered cirri and cumuli all over the sky	88 88	8.15	Do	94 94	7.79	Scattered cumuli
„ 20	97 97	7.11	Scattered cumuli	92 92	8.35	Scattered K			Cloudy
„ 21	87 87	7.77	Do	91 91	7.58	Scattered cumuli			Do
„ 22	86 86	6.92	Fracto cumuli	91 91	7.19	Scattered Fk almost all over the sky	92 92	6.52	Scattered cumuli
„ 24	85 85	7.35	Clear	93 93	7.18	Clear	95 95	7.54	Clear
„ 25	85 85	8.02	Do	94 94	7.42	Do	95 95	6.35	Do
„ 26	85 86	6.89	Do	91 91	7.21	Sky pale and scattered Fk	93 93	6.36	Do
„ 27	86 86	7.15	Do.	91 91	8.29	Clear	94 94	7.66	Do
„ 28	86 86	7.28	Do	90 91	7.58	Do	90 90	7.36	Do
„ 30	84 84	6.62	Scattered cumuli	90 90	7.39	Scattered fracto cumuli	91 91	6.95	Do
May 2	84 84	7.39	Clear.	89 89	7.71	Scattered cumuli.			

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1880 May 3			Cloudy				92 92	7 13	Scattered cumuli
„ 4			Do	90 90	7 50	Scattered cumuli and fracto cumuli	92 92	6 68	Do
„ 7	79 79	5 77	Sun covered with thin cirri	86 87	6 91	K & Fk	89 89	6 53	Cumuli
„ 8	83 84	7 11	Scattered cumuli	90 90	7 11	Clear			Cloudy
„ 10			Cloudy	87 87	6 88	K & Fk scattered about the sun	88 88	7 06	Scattered cumuli
„ 13	85 85	6 97	Fk	90 90	7 51	Scattered cumuli	92 92	7 21	Fk & K
„ 16	84 84	7 84		89 89	8 04	Clear			Cloudy
„ 17	86 86	7 15	Cumuli			Cloudy			Do
„ 18	85 86	7 71	Cumuli and fracto cumuli	91 91	8 19		93 94	7 91	Cumuli
„ 19	86 87	7 75	K & Fk	92 92	8 08	Fk & K	94 94	7 42	K & Fk
„ 20			Cloudy	93 94	7 17	A thin piece of cirri covered the sun			Cloudy
„ 21			Do	88 88	8 01	Scattered cirri	96 96	7 33	Scattered Cs
„ 22	88 88	6 63	Clear						
„ 26	85 85	6 29	Cirri and cirrostrati			Cloudy			Cloudy
„ 27				92 93	7 20	Scattered Fk and K	95 95	7 02	Cumuli
June 10	86 85	6 19	Scattered cumuli			Cloudy			Cloudy
„ 11	86 86	6 37	Do	91 91	7 00	Scattered K & C and a thin piece of C covered the sun			Do

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1880 June 1	87 87	8 27	Scattered cumuli almost all over the sky			Cloudy			
„ 19	94 94	5 55	Pale sky	94 94	6 06	Sky pale and scattered Ck	96 96	5 59	Scattered cumuli
„ 25			Cloudy	87 87	7 51	Thin piece of Ck covered the sun			Cloudy
„ 26			Do	87 88	8 90	Passing Fk round the sun			Do
July 14	84 85	7 88	Scattered cumuli all over the sky	89 89	8 41	Scattered cumuli all over the sky	91 91	7 33	Cumuli all over the sky
„ 23				89 89	8 42	Scattered K			
„ 24	85 86	7 17	Cumuli			Cloudy			
Aug 9				87 87	6 49	Scattered C Cs & K all over sky			
„ 10	87 87	6 86	Scattered K & C all over sky	87 88	6 60	Scattered K & C all over sky	86 86	6 41	Scattered K & C all over sky
„ 21	85 85	5 40	C & K all over the sky						
„ 27				84 84	7 29	Covered with cirri	88 89	5 12	Covered with Ck & K & C
„ 29	84 84	7 56	K & Fk	89 89		K & Fk			Cloudy
Sept 1			Cloudy	85 85	7 52	K and Fk			Do
„ 8				84 85	8 64	Scattered K & Ck			
„ 13	85 85	7 24	Scattered cumuli						
„ 17	83 84	8 32	K						
„ 18				85 85	8 19	Scattered K	89 89	7 95	Scattered K
„ 25	82 82	7 47	Scattered K & Fk	88 88	8 13	Scattered K, C & Fk	87 87	7 81	Scattered cumuli

Date	Two hours before apparent noon: Approx temperature of air	Increase from direct solar radiation	Remarks	At apparent noon: Approx temperature of air	Increase from direct solar radiation	Remarks	Two hours after apparent noon: Approx temperature of air	Increase from direct solar radiation	Remarks
1880 Sept 27	83 83	7 11	Sky covered with cirri						
29				81 81	8 57	Patches of K over the sky			
30			Cloudy	88 88	7 90	Small pieces of passing K passed over the sun during both the times of exposure			
Oct 1	[illegible] 85	[illegible] 09	A few patches of K						
2				89 89	8 11	Thin cirri covered the sun	92 92	6 67	Cumuli
6	84 84	7 05	Patches of K	90 90	8 28	Sky pale patches of C around the sun and K near the horizon			
„ 11	83 83	8 43	Scattered K						
„ 12	87 88	3 18	Do						
22				87 88	8 08	A piece of K covered the sun	91 91	7 72	A few p… of cum…
23	84 84	6 33		90 90	8 01	Scattered K	92 92	8 21	Do
25	83 83	6 84	A few patches of K	87 87	8 10	A few patches of K	90 90	7 00	A few p… of K
27	83 83	8 83	Scattered K	85 86	8 77	Scattered K & K			Cloudy
„ 28	93 93	7 97	Clear	92 92	8 11	Do	81 80	7 07	Cumuli
29				88 80	8 14	Sky pale	92 92	7 07	Sky pale
30	82 82	7 22	Pale sky	86 86	8 07	Do	80 80	7 12	Do
„ 31	78 78	7 73	Do	86 87	8 78	Pale sky and scattered thin cirri	80 90	8 13	Scattere… and pa…

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remar
1880 Nov 1				[illegible]	7 85	Thin cirri covered the sky			
9	77 77	7 12	Patches of Ci round the sun			Cloudy			Cloudy
„ 10				84 84	8 12				
„ 11	76 76	6 80	Hazy	84 84	7 01	Sun covered with thin C			
12	77 77	7 12	Clear	85 86	8 33	Clear	88 88	7 10	Clear
13	73 73	7 03	Pale sky	81 81	8 5	Do	8[illegible]	8 01	Do
14	72 72	7 93	Clear	83 84	8	Do	[illegible]	8 08	Do
16	75 75	7 07	Sky pale	[illegible]	8 28	Scattered Ci and the sky pale	86 85	8 23	Scattere muli
17	81 81	7 80		93 93	7 93	Do	88 88	7 93	Fk & K
18	78 78	7 61	Hazy			Cloudy			Cloudy
20	74 74	6 66	Sun covered with C	81 81	6 79	Sun covered with cirri			
22	72 72	7 36	Covered with cirri			Covered with cirri and the observations rejected			
„ 23	77 77	8 26		81 81	9 15	K & C around the sun	82 82	9 07	Scatter
24	72 72	8 16	Clear						
„ 25	76 76	6 88	Scattered Ck and hazy	80 80	8 13	Scattered K & Fk sky pale	81 81	7 32	K
26			Sky pale and the observations rejected	80 80	7 07	Scattered K & sky pale			Cloudy
„ 27				81 81	7 11	Do	86 86	7 31	Scatter muli
„ 28	78 78	7 02	Scattered C & pale sky	81 81	8 57	Scattered C	84 84	8 05	Scatte pale

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1860 Nov 29	7[illegible] 75	8 11	Clear	79 79	9 0[illegible]	Clear	81 81	9 10	Clear
30	73 72	7 0[illegible]	Pale sky	81 81	7 19	Sky pale	82 8[illegible]	7 91	Do
Dec 1	71 7[illegible]	7 [illegible]7	Do	80 80	9 30	Clear	91 91	7 71	Do
2	77 77	6 [illegible]	Sun covered with thin cirri	8[illegible] 8	7 58	Sky pale	9[illegible] 88	6 03	Sky pale
3	79 76	[illegible] 9	Clear	80 80	8 21	Do	81 82	9 21	Do
4	7[illegible] 75	9 10	Do	79 79	8 70	Clear	91 93	9 16	Clear
5	72 73	7 [illegible]3	Do	91 92	9 70	Do			Cloudy
6	79 73	7 01	Hazy	77 77	8 37	Sky pale	83 8[illegible]	9 10	Clear
7	72 72	7 60	Pale sky	77 77	8 05	Clear	81 91	7 8[illegible]	Sky pale
8	74 74	7 77	Hazy	79 79	7 74	Sky pale and passing 1k	93 82	8 13	Do
9	74 74	7 90	Hazy	78 78	7 07	A thin piece of 1k passed over the sun	79 79	7 80	Sky pale
10	73 73	7 03	Clear	77 77	8 [illegible]7	Sky pale and scattered 1k	79 79	7 60	Scattered
11	72 73	7 12	Do	78 78	8 05	Scattered 1k and pale sky			Cloudy
12	74 74	7 80	Do	78 75	8 93	Clear Scattered 1k	91 91	7 70	Clear scattered 1
13	69 69	8 11	Do	78 73	8 12	Clear	79 79	8 18	Clear
14	70 70	7 28	Sky pale	74 74	8 30	No remarks	77 77	8 11	Sky pale
15	72 73	7 20	Sky pale and hazy	79 79	9 00	Sky pale and hazy	80 80	7 43	Do
16	78 73	7 0	Pale sky	78 78	8 03	Sky pale	81 81	7 50	Do
17			Cloudy	80 80	8 [illegible]	Do	84 84	9 10	Do

Date.	Two hours before apparent noon.			At apparent noon.			Two hours after apparent noon.		
	Approx. temperature of air.	Increase from direct solar radiation.	Remarks.	Approx. temperature of air.	Increase from direct solar radiation.	Remarks.	Approx. temperature of air.	Increase from direct solar radiation.	Remarks.
1880. Dec. 19	65 66	7.94	Clear.	73 73	8.21	Clear.	81 81	7.71	Clear.
„ 20	68 68	8.18	Do.	72 72	9.00	Do.	76 76	8.41	Do.
„ 21	68 68	8.10	Do.	73 73	8.95	Do.	76 76	8.09	Do.
„ 22	68 68	7.77	Sky pale.	73 74	8.36	Do.	76 76	8.56	Do.
„ 23	69 69	7.00	Do.	74 74	8.51	Sky pale.	78 78	8.47	Sky pale.
„ 24	68 69	8.36	Clear.	73 74	8.87	Clear.	79 79	7.55	Do.
„ 25	71 71	8.01	Do.	76 76	8.37	Do.	81 81	8.57	Clear.
„ 26	70 70	8.17	Do.	75 75	8.69	Do.	79 79	9.55	Do.
„ 27	68 68	7.37	Sky pale.	75 75	9.07	Do.	79 79	8.56	Do.
„ 28			Very hazy.	73 73	8.44	Sky pale.	77 77	8.06	Pale sky.
„ 29	69 69	7.91	Pale sky.	74 74	8.36	Pale and hazy.			
„ 30	70 70	5.90	Fog and haze.	76 76	8.05	Covered with cirrus.	81 81	7.07	Covered with cirrus.
„ 31			Cloudy.	78 78	7.97	Pieces of passing Fk. covered the sun at intervals.			Cloudy.
1881. Jan. 2	73 73	6.81	Hazy.	78 78	7.72	Sky pale.	81 81	6.56	Fk. sky pale.
„ 3	72 72	7.01	Do.	77 77	7.90	Do.	81 82	7.10	Clear.
„ 7	72 72	7.07	Passing cirri.	74 74	8.35	Scattered cirri.	78 78	8.07	Scattered cirri.
„ 8	71 71	7.57	Sky pale.	74 74	8.00	Clear.	78 78	7.88	Sky pale.
„ 9	69 69	7.07	Clear.	73 74	8.13	Pale sky.	79 79	8.08	Clear.
„ 10	70 70	7.63	Do.	74 74	8.40	Clear.	77 78	7.95	Sky pale.
„ 11	70 70	7.41	Do.	75 75	6.52	Sky pale.	80 80	7.41	Do.
„ 12	71 71	7.18	Sky pale.	78 78	8.36	Clear.	81 81	6.74	Do.
„ 13	69 70	5.90	Hazy.	75 75	7.04	Sky pale.	80 80	6.02	Do.

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1881 Jan 14	70 70	7 18	Sky pale	76 76	9 14	Sky pale	80 80	8 08	
15	70 70	6 99	Hazy	75 76	7 85	Do	80 81	7 98	Sky pale
16	70 70	7 [illegible]	Clear	7[illegible] 7[illegible]	8 63	Clear	79 79	8 14	Clear
17	69 69	6 90	Hazy	75 75	7 78		81 81	7 54	Sky pale
18	69 69	6 9[illegible]	Do	7[illegible] 74	7 53	Pale sky	70 70	8 10	Clear
19	70 70	6 75	Pale sky	75 75	8 21	Do	82 82	8 30	Do
„ 20	70 71	6 43	Hazy	75 76	8 09	Do	81 81	7 82	Sky pale
„ 21	69 69	8 07	Clear	75 75	9 71	Clear	77 77	8 18	Clear
22	69 69	7 1[illegible]	Do	75 75	7 65	Sky pale	81 81	7 74	Do
23	69 69	6 8[illegible]		76 76	7 10	Do	81 81	6 54	Sky pale
24	69 69	6 25	Hazy	7[illegible] 75	7 50	Do	81 81	6 17	Do
„ 25	70 70	6 20	Do	75 75	6 33	Hazy	82 82	6 67	Hazy
26	73 73	7 60	Clear	73 78	7 32	Pale sky	88 88	6 84	Pale sky
27	71 71	6 29	Hazy	76 76	6 54	Sky pale	81 81	6 91	Sky pale
28	72 72	7 75	Do	77 77	7 95	Hazy	82 82	7 72	Hazy
29	71 71	7 1[illegible]	Sky pale	76 76	8 23	Sky pale	81 81	8 33	Sky pale
„ 30	71 71	6 65	Do	76 76	7 11	Do	81 81	6 90	Do
„ 31	71 72	7 79	Do	77 77	8 36	Clear	81 81	7 67	Do
Feb 1	72 72	8 01	Clear	77 77	8 38	Do	81 81	7 70	Clear
„ 2	73 74	7 97	Do	79 79	8 88	Do	84 84	8 35	Do
„ 3	71 72	6 97	Sky pale	79 79	9 04	Do	84 81	8 10	Do
„ 4			Hazy	74 74	8 11	Do	83 83	7 63	Do
5				77 77	8 71	Do	85 85	8 73	A few of c[illegible]

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx. temperature of air	Increase from direct solar radiation	Remarks	Approx. temperature of air	Increase from direct solar radiation	Remarks	Approx. temperature of air	Increase from direct solar radiation	Remarks
1881 Feb. 7	71 71	6.83	Hazy	80 80	8.14	Clear	85 85	7.11	Clear
8	71 74	7.1	Do	7? 79	7.76	Sky pale	84 84	7.71	Hazy
9	73 7?	7.1?	Sky pale	7? 7?	6.29	Do	8? 85	6.35	Sky pale
10	7? 71	7.?5	Do	7? 79	7.97	Do	83 83	6.91	Pale sky
11	73 7?	7.71	Pale sky	78 78	7.39	Pale sky	84 84	7.52	Clear
12	73 7?	7.33	Sky pale	80 80	8.31	Clear	84 84	7.83	Sky pale
14	7? 75	7.?	Do	80 80	7.50	Pale sky	83 83	6.60	Do
15	74 74	5.81	Covered with cirri	78 78	7.71	Scattered cumuli			Cloudy
16	73 73	7.??	Pale sky	80 80	8.13	Scattered thin cirri	85 85	7.13	Scattered cirri
17	78 7?	8.13	Scattered cirri	81 86	8.18	Scattered cirri			Cloudy
18	76 76	7.55	Do	83 83	7.1?	Do	89 89	7.65	Scattered cirri
19	79 80	7.17	Sky pale	86 86	7.39	Sky pale	90 90	7.50	Sky pale
20	76 76	7.67	Clear	83 83	8.13	Clear	88 88	7.91	Clear
21	77 77	7.?3	Do	81 ?1	7.9?	Do	89 89	7.59	Do
22	80 80	7.?0	Do	86 86	7.?9	Do	90 90	7.61	Do
24	81 8?	7.65	Do	88 88	8.10	Do	91 91	7.30	Do
25	81 81	7.34	Do	88 89	7.?5	Sky pale	9? 92	7.50	Do
26	85 8?	7.01	Do	89 8?	8.?7	Clear	93 93	7.98	Do
27	84 84	7.97	Do	90 90	8.10	Do	91 92	7.80	Do
28	8? 8?	8.03	Do	87 88	8.14	Do	90 90	7.77	Do
Mar. 1	83 83	6.67	Sky pale	89 89	7.77	Sky pale	91 92	7.58	Do
2	83 83	?.13	Clear	8? 89	8.73	Clear	91 91	8.22	Do
3	83 83	?.?0	Hazy	89 89	7.1?	Sky pale			

Date	Two hours before apparent noon			At apparent noon			Two hours after apparent noon		
	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks	Approx temperature of air	Increase from direct solar radiation	Remarks
1881 Mar 4			Cloudy	91 91	6 61	Sky covered with thin cirri	94 94	7 41	Sky pale
5			Do			Cloudy			Cloudy
6	75 75	8 13	Clear	81 81	8 07	Clear	85 85	8 41	Clear
7	76 76	8 23	Do	82 82	7 12	Sky pale	86 86	6 01	Covered with thin cirri
„ 8			Cloudy			Cloudy	87 87	6 71	Passing K Fk
9	79 79	6 00	K & Fk	85 85	7 53	Thin pieces of Fk passing over the sun	89 89	6 97	K and Fk scattered over the sky
„ 10	81 81	7 04	Clear	87 87	8 08	Clear	90 90	8 30	Clear
„ 11	79 79	7 04	Covered with thin cirri	86 86	8 13	Sky pale	91 91	7 55	Sky pale
„ 12	81 81	6 80	Sky pale	88 88	7 65	Do	93 93	8 11	Scattered cumuli
„ 13	81 82	7 93	Clear	86 86	8 31	Clear	89 89	8 25	Clear
14	81 81	7 00	Sky pale	87 87		Sky pale	88 88	7 78	Do
„ 15	78 78	6 69	Cumuli and fracto cumuli	85 85	7 82	Do	90 90	7 06	Sky pale
„ 21	77 77	6 60	Cirri	81 81	8 10	Cumuli	84 84	8 30	Cumuli
„ 22	77 77	8 31	Clear	82 82	8 83	Clear	84 84	8 04	Clear

APPENDIX L.

Letters in reply to the Circular Letter of 31st December 1880

From Dr. C. Hornstein, the Observatory, Prague.

TRANSLATION.

Prague, 27th January 1881

In answer to the letter (of the 31st December 1880) from one of the members of the Committee, I have the honour to make the following communications —

1 *Remarks on a series of observations of sunspots from the year* 1860 *to* 1862.

In the years 1860 to 1862, while employed at the Vienna observatory, I made a series of numerous observations of solar spots with Fraunhofer's refractor of 6 inches aperture. A small portion of these observations, as well as the method of observation and the manner of reduction, were published in the 54th volume of the Astronomische Nachrichten.

The accompanying paper contains a list of the days of observation. On each of these days there were as a rule repeatedly determined the positions, in relation to the centre of the sun, of all the sunspots of any considerable dimensions On each day, with a few exceptions, there was also a sketch taken, in which besides the spots the necessary data for the determination of the area of each spot are given, that is to say, both the area of the nucleus and the area of the penumbra separately. The diameter of the sun in these sketches is taken at about 12 centimètres

I shall endeavour to publish the whole series of observations, if not entire at least in abstract. If the catalogue of solar spots observations now in the press should not contain the above-mentioned observations, I shall feel obliged by the Committee inserting them.

2 *On the purpose for which these observations were undertaken.*

The primary intention of this work, as may also partially be gathered from a communication of mine in the 54th volume of the Astronomische Nachrichten, I stated at a meeting of several astronomers in Berlin in September 1860, among whom were present Professor Bruhns, Dr. Forster, Dr. Pape, Herr Lesser, Herr Auwers. My statement was somewhat as follows:—

"Just as in the determination of a planet's orbit we make use of all the observations which are taken at the various observatories, in the same way, in order to determine the elements of rotation of the sun, all the larger sunspots should be carefully observed at several observatories, and their relative positions to the centre of the sun should be as often as possible laid down. Out of the total of these measurements from month to month, and from year to year, it would then be easy to determine very accurately the elements of rotation of the sun and the movements which are taking place in various parts of the photosphere.

"But these measurements and the calculations based upon them should not be continued for a few years only. On the contrary, the movements on the surface of the sun should be uninterruptedly noted in the same way as this is done with the movements of the moon and the planets, as it is only in this manner that the laws

which govern the former movements can be easily and surely recognized."

Since then, though many publications have rendered a great deal of service, yet the realization of the above methods seems to promise a large harvest of results. For instance, among other questions there might be made an exhaustive investigation whether the period of rotation of the equatorial zone is to be taken as constant.

The work which I began at the observatory of Vienna was interrupted by my leaving that place in September 1862, and unfortunately I am not now in a position to think of continuing it. Perhaps the Committee will feel inclined to take up the examinations pointed out, among the works which will have to be conducted by the contemplated Institute for Astronomical Physics

(Signed) DR. C. HORNSTEIN.

From Professor C. A. Young, Princetown, New Jersey, U.S.A.

Princetown, New Jersey, U.S.A.,
5th February 1881.

I received your communication on behalf of the Solar Physics Committee some days ago, and have been greatly interested in it and in the documents which accompanied it.

I agree entirely with the views of the Committee as to the importance of a continuous daily record of the sunspots and the now quite equal importance of an actinometric record as complete and continuous as possible. It appears to me that at present especial value attaches to actinometric work, and that every effort should be made both to increase the sensitiveness and accuracy of the apparatus and to secure observations, complete and continuous, from stations where the atmospheric difficulties are a minimum.

It is hardly necessary for me to say that I consider it also very desirable that the magnetic records should be carefully collated with observations of sunspots and prominences, especially with such spectroscopic observations as indicate violent disturbance of the solar surface. Certain observations of my own in 1871 and 1872 led me to think it probable that every serious solar disturbance is reflected in the conditions of terrestrial magnetism, and everything which has since come to light, and especially the recent investigations of Professor W. G. Adams, confirm the idea.

It will give me the greatest pleasure to co-operate with the Committee so far as is in my power. I am so circumstanced that I could hardly undertake *continuous* series of observations, because my time is not at my command, being much broken up by various duties; but I have a good deal of leisure in the intervals which I should be glad to devote to whatever form of solar observation, especially spectroscopic, most needs attention. It is my purpose during the coming season to give special attention to sunspot spectra, and I shall be most happy to communicate to the Committee any data I may obtain.

I shall be very glad to receive suggestions from the Committee as to any work they would specially like to have me look after. My apparatus is such that I can most easily make spectroscopic observations, but I think I could, without difficulty, arrange for any other observations of more immediate importance.

I enclose a paper containing a summary of certain spectroscopic observations made here during the past year

(Signed) C. A. Young

Letter from Dr. Buys Ballot, Utrecht

Utrecht, 22nd February 1881.

I feel very much honoured for your communications to me of your views on the methods of carrying on observations in Solar Physics, and I deplore only that I do not feel myself able to aid you in your work.

The Dutch Meteorological Institute has, to my deep regret, no personal or material assistance enough to make these observations, in which I take a very great interrst.

With great pleasure I saw that you (copy of correspondence) lay great weight on a great clearness of atmosphere on high mountains, which I think indispensable, *vide* "Changements périodiques de température dependant du Soleil et de la Lune, Utrecht 1847."

2. That you will (Preliminary Report) examine and discuss short periods; that of Mr. Balfour Stewart. As soon as I have made up the result of my own period of 27·682 days given in the above said Changements, and now confirmed by Professor Bruhns in his letter to me, I will have the honour to offer you a copy of that paper.

3. That the observations will be made with a good actinometer of Professor Balfour Stewart, which perhaps gave occasion to Mr. Violle (Rapport au Congrès météorologique de Rome, Utrecht 1878) to imagine his

I beg you to excuse that I subjected these three points to your attention in order to show you that I perused the papers you favoured me with, and amongst which plans, designs, and remarks of the highest interest are to be found

(Signed) Buys Ballot.

From Sir G. B Airy, K.C.B., M A , F R S., Astronomer-Royal.

Royal Observatory, Greenwich,
3rd March 1881.

I received your letter of December 31st in the country I have kept it in sight, and have referred to it from time to time, but business which seemed to demand my attention every moment has prevented my answering it. I fear that what I have to say now will not be very complete

The objects to which the correspondence (enclosed with your letter) applies, appear to be these, or principally these —

1. The nearly continuous photographic register of solar spots

2. The nearly continuous register of the sun's radiant heat.

1. I suppose that the uses of the solar spot register are two. (*a.*) for the changes from year to year, (*b.*) the changes from day to day.

Now on (*a.*) we have a great deal of information beginning from Wolff, and going on regularly at Greenwich, and I suppose at other places. On what they show the best evidence is that in Mr Ellis' paper on the comparison of the spot observations with magnetic observations. The exhibition (incidental to that comparison) of the numerical record of sunspots shows in short periods extreme irregularity, and in long periods an approximation to an order—

I cannot call it a law—of a rude kind, which cannot be stated without leaving ample license for departure from anything like law The question (as regards the matter before us) applying to this is—Is there reason for believing that we should approach nearer to order or law by multiplying the observations on the proposed scale? I do not think there is Is it worth the trouble to keep up the present system? I think it is It gives us, though in a very rude shape, a cosmical recurrence of much interest, and it gives us the first grounds for thoughts on causal connexion that might in time suggest distinct reasons for extensive observations in India or elsewhere.

In (*b*.) are such phenomena as the rise of spots and faculæ, the diminution of spots, &c, the bridging across spots, the changes that go on in their spectroscopic phenomena, the definition of the solar regions which they most affect, &c &c. The record of these, at Greenwich for instance, is very imperfect But it is not contemptible. There are to be found, in comparison of consecutive photographs, a great number of instances of every result of changes from day to day that can be suggested. I think that until these have been well *studied*, with the view of ascertaining how observations can be extended advantageously at home, and on what points (*very distinctly indicated*) observations at other stations are *wanted*, we should be wrong in undertaking a series, though in itself better at a distant station.

2. The record of solar radiant heat, as a broad natural fact, unconnected (at the present time) with theory, appears to me well deserving of attention Its bearing on almost everything in human life is evidently important. And its bearing on possible cosmical theories may be valuable (though I would not act on anything so vague, except in conjunction with more distinct reasons). But there appears to be at present a difficulty as to the mode of measuring It does not appear, I think, that we have a satisfactory actinometer. Our thoughts ought first to be directed to that instrumental arrangement.

In the meantime there is another mode of measuring the radiant heat as received by the earth—that indicated by the deep sunk earth-thermometers. The evidence of their efficiency as distinguishing the heat received in different years and in different months will be found in "Reduction of 20 years' photographic, &c., and 27 years' observation of earth thermometers, &c., at Greenwich," especially Plates IX. and X. I took the liberty some months ago of suggesting this to the Committee on Solar Physics, and I take the present opportunity of repeating my confidence in its value.

(Signed) G. B. Airy.

Extract from a Letter from the Rev. Dr Robinson.

I prefer the programme contained in the report by Professors Stokes and Stewart to the more ambitious one of Professor Adams's memorial.

It is far more economical, and, with some modifications, might be made much more effective.

As to the second head of their subject, Solar Photography, they show conclusively (Par. 8 and 9) that it can only be worked effectually at an elevated station in India, where a great physical observatory is out of the question. I would only suggest in addition that the photoheliograph used should be of sufficient aperture; I see there

is one 6″ at South Kensington, but even this is scarcely large enough. The instrument should be able, if required, to give pictures like those which Janssen obtained Yet more, it seems from Article C. of the appendix to the Preliminary Report that the absorption lines of metallic vapours vary with the temperature (as I understand the words) If this be so, photograms of solar spectra might give information of changes in the solar atmosphere. I see from Grubb's Catalogue that the price of a 10-inch object glass is 200*l.*; if the instrument were to be used for solar work only its mounting might be much simpler and cheaper than the equatorials intended for accurate micrometer observations.

The first head includes Solar Spectrology and that of Terrestrial Elements. It seems to me that its inquiries can be as effectually followed out at South Kensington with its present appliances described in Appendix IV. as in an observatory established for the special purpose. Three things, however, occur to me as desirable: (1) no observer can be found for the spectral part more competent than Mr. Lockyer, but it would be well if some eminent chemist were associated with him who would be reponsible for the purity of the bodies submitted to examination; (2) as the highest temperature employed will be obtained by electric discharges, the currents which produce any notable phenomena should be measured, for I have no doubt that before long we shall be able to determine the temperature of these discharges; (3) it is certain that the highest temperature which can at present be produced is that of the spark of an inductorium combined with a Leyden condenser, its intensity depending on the quantity of the current and the rapidity of the discharge. Now I wish to point out that quantity cannot be inferred from the length of the spark. Taking two inductoria equal and equally excited, if we connect them consecutively the current of the pair will be q p, equal to that of one, but the spark twice as long, if connected collaterally the current will be doubled, but the spark remain the same This rule holds for more than two, and it follows that for spectrum work a given quantity of wire will be most effective when divided into sections joined collaterally, but each of sufficient electromotive power to give a strong discharge through the vapour experimented on when combined with a condenser. My own instrument was made so. At first it had two secondary coils, each with about three miles of wire, which with separate primaries were fixed on a stand so that they could be connected in any way; these in series gave sparks of 9 4″ between platinum points when excited by four Groves, when collateral 4·4″, their currents being as 1 000 and 1 913. I afterwards added two other coils, which doubled the last current. It is to be regretted that in Dr. Spottiswoode's gigantic inductorium the sections were not kept separate, so that they might on occasion be used collaterally.

(Signed) T. R. Robinson.

From Mr. Henry F. Blanford, the Meteorological Reporter to the Government of India.

Calcutta, 7th March 1881.

Your letter dated 31st December 1880, with the enclosed copies of Reports and Appendices on subjects connected with the appointment of the Solar Physics Committee and its labours, reached me some weeks since when travelling in Burma, and I have deferred my reply until my return to Calcutta.

2. The subject of Solar Research, more epecially in connexion with meteorology, is one in which I have long felt much interest, and my attention has been more particularly directed to the question of the probable variation of the sun's radiant intensity. In the hope of obtaining better evidence bearing on this question than that afforded by the ordinary Solar thermometers, I commenced regular observations with Professor Balfour Stewart's actinometer at the Alipore Observatory, Calcutta, at the end of 1879. These have been continued up to the present time on all days on which the sky is not much obscured by clouds, and I propose as soon as the observations have been subjected to a preliminary reduction and tabulated to communicate them to your Committee. Meanwhile the observations will be continued with the same instrument

3 A few months since I received from the Secretary of State two more instruments of similar character, intended for observation at Leh. These I am having compared with the actinometer in use at Alipore, and they will eventually be made over to Mr Ney Elias, or to such other person as may be appointed to take the observations at Leh

4 Meanwhile I may observe that the experience already gained shows that at Calcutta the heating effect of the sun's radiation is found to vary considerably on days on which the sky is free from visible clouds, except in so far as the presence of diffused cloud may be inferred from the pallor of the sky, and it appears to me that the almost constant presence of this diffused cloud and haze is an obstacle to actinometric observations, which must seriously detract from the value of the work at Calcutta

5. Another class of observations which have been recorded for the last three years at the Alipore Observatory, and for nearly a year also by Mr. S. A. Hill at Allahabad, is that of ground temperatures down to a depth of 3 feet

6. An abstract of the results at Alipore up to March 1880 is given at page 23 of the Report which I send by book post, and an abstract of the later observations up to the end of January 1881 accompanies this letter

7. I send a copy of a paper in which attention is drawn to some circumstances which evidently affect these ground temperatures It appears to me that while they are of great interest from a meteorological point of view, they depend much more on the state of the atmosphere than on the radiant intensity of the sun, and I am doubtful whether they are calculated to throw much light on the variability of the sun.

8 When despatching the actinometric registers, I shall write again, and describe the conditions under which they have been kept.

(Signed) HENRY F. BLANFORD.

Extract from a Letter from the Earl of Rosse.

Birr Castle, 10th March 1881.

I have been waiting in the expectation of receiving the further papers from the Solar Physics Committee which it was mentioned would afterwards be sent, but perhaps I should not further delay to make a few remarks upon the only question included in those papers sent which I feel disposed to call attention to, that is that of "Solar Radiation"; now, so far as I can see, Balfour Stewart's

apparatus measures only the luminous rays of heat, those of low refrangibility being practically all stopped by the glass lens.

Now, although the problem is essentially different from that of the measurement of lunar radiant heat, where about 18 per cent. only of the total radiation passes though glass, still, I think, we should avoid such a disposition of the apparatus as will practically measure, not the solar heat which has penetrated through our atmosphere more or less laden with moisture, as would be the case with the exposed thermopile, but that which has also penetrated through glass. Taking the piles I used for lunar radiation and the proportion, say, 1 to 80,000 for the heat radiation, and say 50 per cent. for loss at two reflecting surfaces of speculum metal, we should have to reduce the aperture from $(36)^{\prime\prime 2}$ [circular] to $V(\frac{36}{160000})=\frac{36}{100}=\frac{1}{11}$ of an inch to get the same deviation of the needle I only reduced the aperture to $\frac{1}{10}''$ or more, and lowered the magnet towards the needle to increase its directing force. The exposure is given by slightly moving a slide, with the hole in it placed at such a distance from the faces of the piles that the spot of sunlight may cover the same portion of the face of each pile as that covered by moonlight in the telescope. The effect of this was to substitute alternately upon each pile a spot of sky containing the sun's disc for a closely adjacent spot not containing the sun's disc, all else remaining constant. The experiment is so simple and the apparatus so cheap (10*l* for a Thomson's galvanometer, and, I suppose, a pound or two would provide the rest) that I should fancy it would be worth making *in addition* to that with Stewart's apparatus.

(Signed) ROSSE.

From Mr. H. C. Russell, the Government Astronomer, New South Wales.

Sydney Observatory, 26th March 1881.

I duly received your letter of December 31st, 1880, together with the enclosures, for which I am very much obliged. It will give me the greatest pleasure to do as much as circumstances will permit to assist in such a promising investigation as that in which you are engaged, but with the very small staff at my disposal I cannot do much. We have a daily weather map to publish, and regular returns from 189 meteorological stations, and the heavy work involved in preparing a catalogue of southern stars and the measurement of double stars. I have, however, all the necessary apparatus for photographing the sun on the American method, the focal length of the object lens being 53 feet; this I will get to work I have also a photoheliograph made for the transit of Venus, giving a picture of about 4 inches. I can use either, but from what I saw of the American transit photographs I am disposed to think that the horizontal photoheliograph gives a sharper image than the one made by Dallmeyer for the transit of Venus

I shall be very glad if you will advise me which is the better instrument for your purpose. It will be an easy matter for me to get the Dallmeyer photoheliograph altered so as to make the photograph 8 inches instead of 4 as at present. I will also obtain, as soon as I know the maker, one of Professor Balfour Stewart's actinometers for use here.

May I ask you to tell the manufacturer to send me a copy of his price list.

I have one meteorological station at an altitude of 4,600 feet, and may be able to make use of it.

(Signed) H. C. Russell.

From Mr. Charles Carpmael, the Superintendent, Meteorological Office, Toronto, Canada.

Meterological Office, Toronto, Canada,
March 30th, 1881

I regret that pressure of work has prevented my yet giving full consideration to your letter of the 31st December 1880, relative to observations in connexion with solar physics or to the accompanying pamphlets.

I shall endeavor to aid as far as possible in the work so far as the instrumental appliances at my command will admit of. I should also like to take the actinometric observations at this observatory, although they would not be as useful as those taken at great elevations, and I have decided, if the price of the instrument is not beyond my means, to purchase one for the use of the observatory.

I very much regret that I have not a telescope here to enable me to prosecute the spectroscopic observations in which I have never lost my interst, and which I hope yet some day to be able to take up again.

I am sorry to say that Captain Ashe, of Quebec, has for some years past ceased to take solar photographs, so that, so far as I am aware, no observations are being taken of the sunspots within the Dominion of Canada.

(Signed) Charles Carpmael.

From Dr. T Hann, Vienna [undated, but received on 4th April 1881].

Translation.

k k. Central-Anstalt für Meteorologie
und Erdmagnetismus.

I beg to express my sincerest thanks for the receipt of the publications of the Solar Physics Committee, which I read with the greatest interest and satisfaction. In the present position of meteorology any investigations on the variations of the radiant energy of the sun are of the highest importance for the progress of this science. Unfortunately I am not at present in a position to take any direct part in these investigations, but I shall at least endeavour for the future to promote them in our own observatory. Continuous photo-registration of the variations in the three elements of the magnetism of the earth, and the hourly recording of the value of the same at the observatory here, may for the present be taken as an indirect assistance to the researches on the relation between the variations in the condition of the sun and the variations in the physical condition of the earth's surface. If I may be allowed to express an opinion how the question of the variations in the intensity of the sun's radiation on the surface of the earth can perhaps in an indirect way be brought nearer to a solution, I would recommend that observations be taken of the temperature of the earth in India, especially in the driest part of the N.W. Provinces, or of the Punjab, where the penetration of meteoric water will have little influence on the ground temperature, and where the conditions of the population are most favourable.

Leh in Thibet appears to offer particularly favourable conditions for such observations.

(Signed) Dr. T. Hann.

From Professor Newcomb.

Nautical Almanac Office, Navy Department,
Washington, D C., 15th April 1881.

I have the honour to acknowledge receipt of your communication, circular, and papers of December 31st last, and of papers since forwarded by the Secretary of the Solar Physics Committee.

My long delay in replying has arisen from the fact that I have given no such special attention to the subject as to form an opinion worthy of appreciable weight. I may, however, be permitted to offer a single suggestion, although it is one which cannot have escaped the consideration of your Committee.

In view of the fact that observatories especially devoted to astronomical physics and observations of the sun already exist near Paris and Berlin, which observatories may be assumed to give records as good as any that can be obtained in the unfavourable climate of Western Europe, it would seem that the most promising direction which new activities could now take, would be that towards establishing an observatory in a superior climate, and in a longitude as distant as possible from observatories now in activity. I would especially call your attention to a paper by Mr. S. P. Langley, presented to the French Academy of Science on the 21st ultimo, in which he shows that the accepted determination of the amounts of solar energy received by the earth are largely in error from the effect of atmospheric absorption. To make any real advance in this and similar directions it is necessary to have a situation at the most elevated position and in the most transparent atmosphere practicable.

(Signed) Simon Newcomb.

From Senhor Capello, Observatory, Lisbon.

Translation.

Lisbon, 18th June 1881.

I am about to make a tardy reply to your interesting letter of the 31st December last, which I have not sooner answered in consequence of great pressure of business, the routine work of this observatory, which deprives me of all my time, and also on account of the bad state of my health during the early months of this year. For this neglect I must crave your indulgence.

In the first place, I congratulate you on the great step which you and other scientific men of your great country have taken for the advancement of Solar Physics. I think that some months' experiments at South Kensington will advance this beautiful science by many years.

I can scarcely say enough on the chief points mentioned in your letter.

With reference to the collection and publication of sunspots, I would acquaint you that I possess a certain number of negative plates of the sun, about 4 inches diameter, taken during the years 1872 (the end), 1873, 1874, and some which are more recent.

Latterly I have found a great number of these negatives in a very bad state, for I had the bad habit of employing bichloride of mercury to strengthen them.

Notwithstanding, I believe I may still have some dozens of plates which may not be found in your collections, and these I hasten to place at the disposal of the Committee I desired to continue these observations of solar spots, but since I have seen M. Janssen's fine work at Meudon I am much in doubt as to its being worth the trouble to take pictures as I did in former years.

Nevertheless, I purpose taking them again in July or August next.

There is another subject which has a close connexion with sun-spots. This observatory possesses a set of magnetometers similar to that at Kew, which has been in action since June 1863. The results have been published at different intervals, for the declination up to the end of 1871, for the total force, inclination and horizontal and vertical components up to 1868, and there are now in the press these same elements up to 1872.

In the research for perturbations we have followed General Sabine's method. We have found serious difficulties with the bifilar and the vertical. With these two instruments this method induces an error in the number and frequency of the perturbations, principally in the vertical

These two instruments very often change the position of equilibrium after strong perturbations. The co-efficient of temperature not being exactly known, there is always a variation from the normal value at end of each month, due to the difference of temperature. All these causes falsify the results, when one employs the method of comparison between the values of each hour and the normal average of the month

It is necessary to select and extract the perturbations, not directly from the hourly values, but from the diurnal partial variations of each day, compared with the average diurnal variation of each month. The work is somewhat longer, but the results are surer and more exact For this and other questions which relate to these observations it is most necessary that directors of establishments possessing magnetometers should agree together in order to employ the same method in their researches, determination of constants, greatness of perturbations, &c., &c , in order that their results may be comparable.

As to actinometric observations, we have used M Marie Davy's actinometer since 1877. For more delicate researches to ascertain the value of the change of the actinic power of the sun it would be necessary to have a very long series of observations, always making use of the same instrument. M. Marie Davy's actinometer, like all mercurial thermometers unceasingly exposed to the sun's rays, is often put out of working order on account of the mercury, which in the long run fouls the tubes, and by bubbles of air which interpose themselves in the column of mercury The series becomes valueless when one instrument is substituted for another.

I once more congratulate you that, assisted by truly scientific men, you are making the science of Solar Physics and its relations to meteorology and the physical globe advance with giant strides.

(Signed) J. Capello.

War Department,
Office of the Chief Signal Officer,
Washington City,
November 9th, 1881.

SIR,

YOUR valued communication of December 31st, 1880, as you have already learned, through some mishap failed to reach me, but a second copy, together with the enclosures, has been kindly forwarded and received

You will be pleased to learn that the subject of Solar Physics has already been considered by me as one of fundamental importance in Meteorology, and that I had already in April last taken steps toward the investigation of the total amount of solar heat received by the earth; and to this end Professor S. P. Langley has during the last summer occupied the summit of Mount Whitney, Cal., where, at an altitude of over 14,000 feet, many important observations have been made, a full account of which you will, of course, receive when published by this Office.

The general subject of solar and terrestrial radiation is also being provided for by the introduction of Violle's Conjugate Bulbs and Marie Davy's Conjugate Thermometers at a number of Signal Service Stations. Corresponding observations of the standard actinometer at this Office will, of course, be made. Observations of the solar spots are made for this Office by Professor D. P. Todd, now of Amherst, Mass. I shall be glad to have these conducted on a system uniform with those of European observers, and will be obliged to you for any suggestion you may make. If practicable I may even entertain the proposition of maintaining a series of daily photographs of the sun's surface, unless indeed some other of your American correspondents may have already undertaken this work.

With assurance of my high regard,

I am, &c,

J. F. B. HAZEN,
Brig. and Bvt. Maj. Genl,
Chief Signal Officer, U.S.A.

Professor G. G. Stokes,
Science and Art Department,
South Kensington, London, England.

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SECOND REPORT

BY THE

COMMITTEE ON SOLAR PHYSICS

APPOINTED BY THE

LORDS OF THE COMMITTEE OF COUNCIL ON EDUCATION.

Presented to both Houses of Parliament by Command of Her Majesty.

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I.—PROCEEDINGS OF THE COMMITTEE.

1. Introductory.

At the commencement of the period with which the present Report deals, December 1883, the Solar Physics Committee was constituted as follows:—

Professor G. G. Stokes, Secretary R.S.
Professor Balfour Stewart, F.R.S.
Mr. W. H. M. Christie, Astronomer Royal, F.R.S.
Mr. Norman Lockyer, F.R.S.
Lieut.-General Strachey, R.E., F.R.S.
Col. Donnelly, R.E.
Capt. Abney, R.E., F.R.S.

Subsequently, in July 1885, the following were added:—

Professor J. C. Adams, F.R.S.
Professor Rev. Dr. Pritchard, F.R.S.
Rev. J. S. Perry, F.R.S.

In November 1887 Professor Stokes retired from the Committee on his election as a member of Parliament, and in the February following occurred the death of Professor Balfour Stewart.

The Committee expressed to Professor Stokes the extreme regret with which they had learned his decision to retire, and they recorded their appreciation of the great value of the assistance which he had so readily and generously accorded to them.

On being informed of the death of Professor Balfour Stewart, the Committee recorded their opinion of the great loss which science has sustained by the death of one whose researches have been among those on which the science of Solar Physics has been based.

Professor G. H. Darwin, F.R.S., and Mr. H. Blanford, F.R.S., having been invited to join the Committee, took their seats at the meeting held on the 9th March 1889.

Since the date of the last report, November 1884, the Committee have had 15 formal meetings, and 61 since their appointment in 1879. In addition to the discussions carried on at the meetings, several members of the Committee have undertaken and carried out special branches of inquiry, to which reference will subsequently be made.

In accordance with the arrangements made on the appointment of the Committee, Mr. Lockyer has continued in charge of the observational and experimental work carried on at South Kensington.

The Committee have been in frequent correspondence with the Indian Government and with British and foreign men of science interested in Solar Physics.

In their first Report the Committee included a brief review of the state of knowledge of Solar Phenomena at that time, and of the steps being taken in this and other countries to increase it. Although this general statement was then thought desirable, as explanatory of the objects which the Committee had been formed to further, there are obvious reasons why a body constituted as it is should not appear to assume a position of authority in treating of the many questions that arise in connexion with Solar Physics, and they therefore do not propose to continue the publication of such a review as that above referred to.

The more important subjects that have come under the consideration of the Committee since their last report was prepared will be briefly stated.

2. Total Eclipses of the Sun.

Eclipse of 1883.

Mr. Lockyer, on behalf of the Committee, entered into communication with the Royal Society Eclipse Committee, and the arrangements agreed to were reported at the 43rd meeting. These will be found in detail in Appendix No. I.

Eclipse of 1886.

In the eclipse expedition to the West Indies in 1886, organised by the Royal Society, the Solar Physics Committee was represented by Mr. Lockyer. The instruments employed by him were :—

(1.) A coronograph, consisting of a long wooden camera fitted with a 6-in. Henry photographic object glass, and mounted on the head of his own 6-in. equatorial ;

(2.) A Dallmeyer photoheliograph with 4 in. photographic object glass belonging to the Greenwich Observatory.

Mr. Lockyer was stationed at Grenada, but he was unfortunately prevented from making observations by the unfavourable state of the weather.

A communication from Professor Tacchini relative to the observations that it was desirable to make will be found in Appendix II.

Eclipse of 1887.

No special measures were deemed requisite in connexion with this eclipse, it having been understood that all needful steps would be taken by the Russian astronomers

3. SOLAR PHOTOGRAPHS AND TABULATION OF THEIR RESULTS.

A memorandum was presented by Professor Balfour Stewart in March 1883 on the work necessary to complete the record of sun pictures up to the end of the year 1887. The Committee were of opinion that this is a very valuable and necessary investigation for the advancement of our knowledge of Solar Physics, and they requested the Astronomer Royal and Professor Balfour Stewart to consider and report on the above memorandum, and generally on the best method of tabulating sun-spot data (*see* Appendix No III.). The suggestions made in this report were adopted by the Committee.

A letter from Professor Stewart relative to the proposed method of recording daily information regarding sun spots, together with the observations of the Astronomer Royal and of Professor Stokes thereon having been considered, the Committee resolved that the rejection of spots near the limb was not desirable, and that it was expedient that the daily sums of projected areas should be given as well as those corrected for foreshortening.

In view of the presumed superiority of the 8-inch photographs of the sun over the 4-inch, it was resolved that the Indian Government be requested to revert to the 8-inch photographs, 12-inch photographs in addition being taken when the atmosphere is particularly clear, and that steps be taken to induce the Directors of Observatories possessing photoheliographs on the Greenwich pattern to have them adapted to take 8-inch pictures.

In reply to an inquiry by Colonel Haig, R.E., relative to silver and cyanotype prints of Indian photographs, and a

desire to know whether the latter will answer the purpose of the Committee, he was informed that the substitution of the cyanotype for the silver prints hitherto sent would break the series, and that, therefore, unless he is particularly anxious to do so, the Committee would prefer not to make the change.

At the 52nd meeting, February 1886, Mr. Lockyer reported that all the Indian photographs, up to the date from which the work was taken up at Greenwich, had been reduced, the reductions to 1st January 1881 being ready for press. He suggested that the copy should be sent to Greenwich for examination. This was agreed to.

At the following meeting, April 1886, the following arrangement was discussed and adopted by the Committee:—

1. The areas and positions of all spots and faculæ on photographs obtained by the Committee, whether for past or current dates, to be determined by the Astronomer Royal, for each day on which there is no Kew or Greenwich photograph, to supplement the Greenwich series, which has been accepted as the standard series by the Committee.
2. The photographs obtained by the Committee to be examined, and the best photograph for each blank day at Kew or Greenwich to be sent to Greenwich for reduction, as soon as possible after their reception.
3. The reduction for back periods to be undertaken as soon as the pressure of work caused by the recent maximum of sun spots becomes less. It will probably be sufficient to limit these reductions to the determination of areas for each day, together with the approximate positions of such spots as have not been measured on the Kew or Greenwich photographs.
4. The tabulated results from all photographs from 1885 inclusive, to be printed in the "Greenwich Observations," and, if desired, a number of separate copies, say 50, to be struck off for distribution by the Solar Physics Committee as part of their publications. The results from photographs previous to 1878 to be printed as an Appendix to the "Greenwich Observations," and a number of separate copies to be struck off for distribution by the Solar Physics Committee, the joint origin and nature of the work being stated.

5. To facilitate work on spot spectra and discussions other than those of area and position of spots, the proofs of the "Greenwich Photographic Results" as soon as received to be sent to South Kensington, and also when required the Greenwich numbering of the spots observed at South Kensington.
6. Also, when required, negatives to be exchanged between South Kensington and Greenwich so as to form a second series in the Science Museum as a safeguard against loss by fire or otherwise.

Mr. Lockyer was requested to prepare a specimen of the plate and accompanying data which he proposed to publish embodying the various information collected at different observatories; also to obtain an estimate of the cost of preparation and of reproduction.

Mr. Lockyer reported that it had become necessary to readjust the slit of the Photoheliograph and the cross wires, and requested authority to ask Mr. Dallmeyer to do this; also to provide a tertiary magnifier, at an estimated cost of 15*l*., to test the possibility of obtaining large photographs of the sun spots in this manner.

4. Solar Spectroscopic Observations.

In February 1886 Mr. Lockyer reported that 700 observations of spot spectra had been made and 200 finally reduced. The Committee directed that the observations should be printed and circulated together with the necessary maps.

Mr. Perry was invited to prepare his observations on the spectra of sun spots between D and B in the same form as Mr. Lockyer's observations in order that they may be published together.

Mr. Lockyer reported that the spectroscope which had been lent by the Indian Government had been recalled, and that the commencement of a series of observations taken under new conditions was thereby necessitated. A spectroscope would be required.

A communication was directed to be made to the India Office suggesting that spectroscopic observations of sun spots should be undertaken at the Elphinstone College at Bombay with the instruments which had recently been provided for that institution.

5 Professor Roscoe's Actinometer

A suggestion having been made that the actinometer of this pattern, which was in the possession of the Science and Art Department, might be tried at Lé, inquiry was made of Mr. Blanford, the Director of the Indian Meteorological Department, which resulted in the proposal being dropped as arrangements for a continuous record could not be secured.

6 Professor Balfour Stewart's Actinometer.

The results of observations during the years 1884 and 1885 made at Lé with this instrument were communicated to the Committee, and a note on the subject by Professor B. Stewart was submitted by him.

It was reported that endeavours would be made to secure the continuance of observations with this instrument in India.

7. Connexion between Solar Variability and Terrestrial Phenomena.

Professor B. Stewart submitted a paper on a comparison between sun-spot variability and terrestrial magnetic declination inequalities of short period between 24 and 26 days, which has since been printed in the Proceedings of the Royal Society.

In reply to a request of the Committee, the Meteorological Council stated that they were not in a position to undertake an inquiry into the connexion between solar variability and terrestrial meteorology, which they thought might be better carried out in India, and they suggested that the co-operation of the Indian Meteorological Department might be invited. They likewise stated their opinion that there was no instrument at present suited for obtaining regular records of solar radiation by ordinary observers, such as those on whom the Council had to rely.

Professor Darwin, Mr. Blanford, and Captain Abney were requested to consider whether any instrument could be found or contrived which would supply a more simple and effectual means of observing the sun's heat than the ordinary radiation instruments hitherto employed.

8. International Co-operation in Sun Observations.

Mr. Lockyer having undertaken, with the approval of the Committee, to confer with the directors of the principal

Solar Observatories in Italy and France on the method of observation and record of Solar phenomena, presented a Report on the subject which will be found in Appendix IV.

On consideration of M. Janssen's recommendations (which will be found in his letter annexed to Mr. Lockyer's Report), it was resolved that his suggestions were of such high value and practical character that they should be accepted as indicating the most suitable course to be followed for the further prosecution of the study of Solar Physics.

It was also resolved that the first step should be the formation of a preliminary International Committee on organisation, and the Committee expressed a hope that the Science and Art Department would obtain the necessary approval of Her Majesty's Government. The Committee, however, thought it desirable, first, to obtain the opinion of the President and Council of the Royal Society on these proposals, which in their estimation were of the highest scientific importance.

On receipt of the reply of the Royal Society, which was favourable to the contemplated action, the Science and Art Department was requested to invite the under-mentioned men of science engaged in Solar research to meet in London in order to confer with the Committee on Solar Physics with regard to the co-operation of observers in all parts of the world in Solar research, and to consider the particular proposals made by Dr. Janssen—

Dr. Bredichin.
Dr. De la Rue, F.R.S.
Dr. Huggins, F.R.S.
Dr. Janssen.
Professor Konkoly.
Rev. S. J. Perry, F.R.S.
Professor E. C. Pickering.
Professor Respighi.
Professor Ricco.
Dr. A. Schuster, F.R.S
Professor Spörer.
Professor Struve, or his delegate.
Professor Tacchini.
Dr. Thollon.
Dr. Trépied.
Dr. H. E. Vogel.
Professor Wolf.
Professor C. A. Young.

In reply to this request the Committee received the following extract from a Minute of the Department :—

"My Lords consider the report of the Solar Physics Committtee of November 1882, together with their recommendation of the 19th December with regard to the establishment of an organisation for promoting the study of Solar Physics by International Co-operation.

"With this recommendation my Lords entirely concur and are prepared to issue the necessary invitations to the persons named at such time as the Solar Physics Committee may deem desirable.

"My Lords understand that the recommendations of the Solar Physics Committee contained in their last report are being carried out as far as the means at the disposal of the Department permit. It would appear that the time has arrived when, whatever may be the outcome of the negotiations with foreign observers, a reorganisation of the functions of the Solar Physics Committee is called for The necessity for, and the lines on which, future work should be conducted having now been so clearly laid down by the valuable labours of the Committee, their services in future will be required more in supervision and consultation than in initiation and direction. And my Lords have arranged the future appropriation of the grant for Solar Physics in the next financial year with this view with the Lords Commissioners of Her Majesty's Treasury.

"While thanking the Members of the Committee for their past services, my Lords trust they may still count on their valuable assistance in the future. They propose to add Mr. Warren De la Rue, F.R.S., D.C.L., LL.D., Mr. W. Huggins, F.R.S., LL.D., and the Rev. S. J. Perry, F.R.S., to the Committee, with Professor Stokes, Sec. R S., D.C.L., LL.D., as Chairman."

Letters were accordingly written to the gentlemen abovenamed, inquiring whether, in the event of invitations being issued to a conference in London, it would be convenient for them to attend. The replies to this inquiry will be found in Appendix No. V. They showed that it would be very difficult to hold the suggested conference, and the idea was abandoned, at any rate for a time.

It was, however, resolved that a further communication should be made to the directors of the chief solar observatories explanatory of the views of the Committee on the subject of international co-operation in the preparation and publication of solar observations. A copy of this communication will be found in Appendix No. VI.

9. Status of the Committee.

At the 55th meeting of the Committee, held on 17th January 1887, Colonel Donnelly communicated the following extract from a letter received from Her Majesty's Treasury and dated 14th January 1887 :—

"They (their Lordships of the Treasury) must also adhere to their decision to remove the grant to the Committee on Solar Physics from this Estimate, reserving for further consideration the question whether it may be continued in some other form."

The Committee having been invited to state their opinion as to the continuance or abolition of the Committee, prepared the following memorandum :—

In reply to the invitation of the Lords of the Committee of Council on Education to express our opinion on the proposed abolition of the Committee on Solar Physics, several members of this Committee have already shown their Lordships how serious a loss to the progress of science would be the cessation of the investigations and of the collection and discussion of data now carried on by the Committee. They have also pointed out that, so far as they are aware, there is no other body in the country in a position to take up this line of inquiry, which, in the opinion of so many men of science, has so important a bearing, not only on the advancement of abstract science, but also on the elucidation of industrial and commercial questions of the highest importance. The Secretary of the Science and Art Department has now informed the Solar Physics Committee that the Lords Commissioners of Her Majesty's Treasury have determined to remove the grant to the Committee from the Estimates of that Department, reserving for further consideration the question whether it may not be continued in some other form.

With reference to the question which it is stated is to be reserved for further consideration, the Solar Physics Committee feel that it is right that they should point out that any break in the continuity of the work which they have been organising and conducting during the last nine years will be most detrimental to the cause of science. It would, moreover, render comparatively useless much of the work which has been already done, and the money which has been hitherto spent.

The efforts of the Committee have been chiefly directed to securing daily systematic and continuous records of solar phenomena of every kind; of endeavouring to systematize

the work so as to ensure the greatest economy of time and labour; and of trying new and improved methods of observation. One of the main difficulties with which they have had to contend in endeavouring to utilise former work, carried on by different individuals at different places during the last half century, has been the existence of such gaps as would again follow if any break of continuity in the systematic observations established through the action of the Committee were now to be permitted.

They cannot too strongly insist upon the point that the chief value of such observations as those upon which they have been asked to advise lies in their absolute continuity.

At present, in consequence of the organisation which has been established, daily systematic observations of the sun's surface are practically secured by the co-operation of the Indian, Australian, and Mauritius Governments, photographs from one or other of these stations filling up the gaps in the Greenwich series. And considerable progress has been made in devising a satisfactory method of obtaining photographs of sun-spots on a large scale with fiducial lines.

The daily systematic observation of the spectra of sun-spots has also been secured, and already the results obtained from 700 sun-spot observations have indicated the extreme importance of this work.

The daily systematic observation of the prominences has not yet been added to the foregoing, but the Committee are at the present time in communication with the directors of various observatories, colonial and foreign, in all parts of the world, on this subject, and they were not without hope that before very long this also might have been added to the general record available for discussion by the Committee.

The Committee wish it also to be clearly understood that the chief object it has had in view in endeavouring to get a complete record of all phenomena is to obtain from them the information which may be of value either from the point of view of pure science, or of the application of science to the welfare of mankind. It may not be unnecessary, therefore, to point out that even supposing other organizations could obtain these complete records, and could reduce them in the usual manner, even then one of the chief functions of the Committee would still not have been fulfilled. Any of the so-called "reductions" of the observations have for their object merely the setting out of the observations themselves in their best form, but what is required is to know what the observations teach us, and how the facts thus acquired

may be utilised in further inquiries, or for practical purposes.

The Committee have already secured complete photographic records of the sun's surface from the year 1881 to the present time, and they have already begun work in several directions with a view of ascertaining what increase of our knowledge we may hope to obtain from them. The Committee have arranged with the Astronomer Royal that the measurement and reduction of the solar photographs should be made at Greenwich.

On the sun the unit of change, so to speak, is not a day or a year as with us, but it is a period of about 11 years. The full meaning of each cycle of 11 years cannot be grasped unless the observations are practically continuous, and it would be an unscientific mode of procedure to assume that every cycle is like every other—indeed we know that this is not so. A break now, therefore, in observations of the present cycle would not only prevent us from securing complete observations of it, but would react detrimentally on our knowledge of all the others, because our power of comparing one cycle with another would be lost.

Further, our present knowledge leads us to see that if we content ourselves with observations of the spotted area alone we may be discarding branches of work which from some points of view are of higher importance. No study of the spotted area alone, for instance, would have demonstrated the remarkable change in the temperature of the lower strata of the solar atmosphere which has been revealed by the spectroscopic observation of both spots and prominences, and it may be that in a not distant future we may find these indications of varying temperature to be most important from a practical point of view. Bearing this in mind it is needful for us to point out that as a matter of fact the experimental study of the solar spectrum from the point of view of the origin of the Fraunhofer lines and their appearance in various solar phenomena is not being carried on anywhere else but at Kensington.

In what has gone before we have endeavoured to show how important it is that there should be neither break nor diminution in the work on which we have been asked to advise the Government.

We now pass to another point.

The Lords Commissioners of Her Majesty's Treasury appear to contemplate that the various kinds of work under-

taken by the Committee should in future be done otherwise than in connexion with the Science and Art Department.

The work has already entailed much correspondence and arrangements with Colonial and other Governments, which indeed have already voted sums for the purpose of assisting the work of the Committee by utilising favourable local conditions. On this account alone a close connexion between the inquiries in Solar Physics and a Government Department is clearly essential. Further, the work which the Committee have done with the sum allotted to them and with practically no capital expenditure either for buildings, or instruments, has been possible only because they have been enabled to avail themselves of the resources afforded by the Science and Art Department and the Science School at South Kensington.

Physical and chemical laboratories, complete electric installations, telescopes, trained photographers, organisation for correspondence, assistance in performing the various experiments which the Committee has controlled, all these exist already at South Kensington for other purposes and must continue to exist, and they have been made available and utilised without any expense. The Committee think it only right to point out that if the work is to be continued at all arrangements at least as complete as those existing at South Kensington will be essential for the proper conduct of it, and that these will necessarily entail a large initial and yearly expenditure.

The Committee would remind the Government that the question which was pressed upon the latter by the Duke of Devonshire's Commission and the memorial of scientific men in 1877 was the establishment of a physical observatory similar to those erected by the German and French Governments. It was, however, thought by the Science and Art Department that the various means and appliances for investigation which at present exist in connexion with the Science Schools were of such great value, and could by proper management be so well utilised, that only small aid would be needed to render them thoroughly efficient for the purpose sought. It is on these grounds that the Committee have not hitherto found it necessary to advise the erection of the special establishment which would otherwise have been required to give effect to the recommendations of the Duke of Devonshire's Commission.

The Committee in making this representation have been guided simply by scientific considerations. While they have no desire to protest against their own abolition, or any change

of policy on the part of the Government, they wish to place on record their conviction of the national and scientific importance of the work which the Lords of the Committee of Council on Education called upon them some years ago to take in hand, a conviction which led them to place their services freely at the disposal of the Government.

II.—WORK AT KENSINGTON.

The following Report has been drawn up by Mr. Lockyer on the work done at South Kensington. His conclusions based on the results of this work will be found in Appendix No. VII.

(1.) *Instruments.*

The instruments now at the disposal of the Committee are as follows:—

(1.) A 10-inch telescope equatorially mounted, with declination and right ascension circles, made by Cooke, of York. This is the property of the Science and Art Department, and was purchased for the use of students in the Science Schools. The eye end is adapted for a spectroscope attachment.

(2.) A 6-inch equatorial by Cooke, the property of Mr. Lockyer.

(3.) A 6-inch equatorial by Troughton and Simms, lent by the Astronomer Royal. A grating spectroscope is attached to the eye end of this instrument. This is used for the daily observations of sun-spot spectra.

(4.) A photoheliograph by Dallmeyer for taking 4-inch sun-pictures, lent by the Astronomer Royal. A new secondary magnifier and camera have been added, so that the instrument is now adapted for 8-inch pictures.

(5.) A siderostat, made by Cooke, of York, lent to Mr. Lockyer by the Royal Society.

(6.) A $3\frac{3}{4}$-inch achromatic telescope by Cooke, the property of Mr. Lockyer.

(7.) A $9\frac{1}{3}$-inch Browning-With mirror with tube complete, the property of Mr. Lockyer.

(8.) A spectroscope with seven prisms of 45° made by Browning, the property of the Royal Society. This is used for solar work.

(9.) A small grating spectroscope, the property of Mr. Lockyer. The grating is ruled on silvered glass, and has about 17,280 lines to the inch. The instrument is made so that the observing telescope can be replaced by a small camera.

(10.) A grating spectroscope, the property of the Science and Art Department. The grating is by Rutherford and is ruled on speculum metal; the number of lines per inch is about 14,000. The observing telescope has an aperture of $2\frac{1}{2}$ inches.

(11.) A diffraction grating by Rutherford, ruled on speculum metal. This is the property of the Department and is used with a spectroscope in which the scale is observed by a second telescope clamped above the observing telescope.

(12.) A 3-prism spectroscope by Hilger, the property of the Department. The collimator of this instrument is about 5 feet 9 inches long, and the prisms are each 3 inches deep and 6 inches edge. The dark slide used with the camera is so arranged that any part of the plate can be exposed to the spectrum; in this way several parallel spectra can be obtained by successive exposures on the same plate. The photographic lens used is a 4-inch rapid rectilinear by Dallmeyer, the focal length being about 16 inches.

(13.) Spectroscope by Hilger, the property of the Department. In this the prisms are made of Iceland spar and the lenses of quartz. There is one prism of 60° and two halves of a prism of 60°, the prism having been cut into two equal parts by a vertical section through the vertex. One of the half-prisms is placed with the rectangular face immediately in front of the collimator lens, and the other with the rectangular face in front of the object glass of the observing telescope. The observing telescope can be replaced by a camera, the lens used for photography being simply the object glass of the observing telescope.

(14.) A Steinheil spectroscope with three prisms of 30° and one of 60°, the property of the Department.

(15.) A direct-vision spectroscope mounted on a stand by Hilger, the property of the Department.

(16.) A Rowland grating spectroscope, the property of the Department. The grating is a concave one of about six feet in focal length, and has about 17,000 lines to the inch. The available surface of the grating is 5 in. × 2 in. It is mounted on a wooden frame in a hut facing the siderostat. The grating and eye-piece (or camera) are fixed one at each end of a board, the ends of which slide in a pair of grooves at right angles to each other, and the slit is fixed at the intersection of the grooves. The distance between the grating and the camera is twice the focal length of the grating-mirror, so that the slit always lies on a circle described on that line as diameter. This being the case, all the spectra are brought to a focus at the camera. In this way a normal spectrum on an invariable scale is obtained.

(17.) Star spectroscope, by Hilger, having a prism of 60° and two half prisms.

(18.) A 6-inch prism for photographing star spectra.

(19.) A dynamo-electric machine and lamp, the property of the Department.

(20.) Intensity and quantity coils by Apps.

(21.) Small induction coil by Apps.

(22.) A battery of ten large Bunsen cells.

(23.) A short focus 6-inch rapid rectilinear photographic lens by Dallmeyer. Also, a 12 × 10 photo lens by Dallmeyer. Also, two 8½ × 6½ photo lenses by Dallmeyer.

(24.) A 12 × 10 photographic camera with stand, three double and two single slides, by Meagher. This was purchased out of the funds at the disposal of the Committee. The 12 and 10 photographic lens before mentioned is used with this camera.

(25.) An enlarging camera, 15 in. × 12 in.

(26.) Micrometer reading to 100,000th of an inch, by Hilger, for measuring photographs of spectra. This belongs to the Department.

(27.) A small heliostat for use with the spectroscopes, the property of the Department.

(28.) A lathe.

(29.) A 15-inch retouching desk, for the examination of sun-pictures.

These instruments are in use by Professor Norman Lockyer in his laboratory or observatory, or are used for teaching purposes in the Normal School of Science.

The equatorial instruments belonging to the Indian Government with which observations of sun-spot spectra have been made during the last seven years has been returned to the India Office, and has been erected at the Elphinstone College at Bombay. Other arrangements for securing the continuity of the observations therefore became necessary. The Astronomer Royal and the Museum authorities were consulted on this subject, and no objections were made to the employment of the 6-inch equatorial by Simms, which was then on loan to the Museum. This was erected in the observatory previously occupied by the Indian instrument, and the same spectroscope is being used. It became necessary to have an adapter made for this purpose, because the eye-piece end of the Simms instrument was not made to the same gauge as that of the Cooke.

(2.) *Observatory Buildings.*

1. The 6-inch equatorial by Simms has been erected, in a hut with a conical revolving roof, in the ground behind the Exhibition Road Post Office.

2. The 10-inch equatorial, with the added Gautier photoheliograph, is erected in a wooden observatory with a conical revolving dome.
3. The Greenwich photoheliograph is in the hut originally constructed for use in the Transit of Venus Expedition (1874).
4. The siderostat is in a hut running back on a tramway.
5. The Rowland grating spectroscope is in a dark hut facing the siderostat.

All these are in the spare ground behind the Exhibition Road Post Office, and are all in a fair state of repair.

(3.) *Photoheliograph.*

The new instrument, to replace that sent to India, was completed in 1885, and many photographs were taken between that year and 1886. It soon became obvious that there was something wrong about the secondary magnifier, because under very perfect observing conditions it was not possible to obtain the mottled surface of the sun in any way approaching to the perfection secured at Meudon.

Professor Stokes was consulted on this matter, and the upshot of it was that the Department authorised the construction of a new secondary magnifier by Grubb, of Dublin.

The photoheliograph was then re-erected alongside the tube of the 10-inch equatorial. Some time, however, elapsed before some of the fittings were returned from Mr. Dallmeyer, and for the next 10 weeks the sun was rarely, if ever, visible in the observatory. A long time thus elapsed before there was an opportunity of testing the instrument on the sun. In the meantime, however, the magnifier was subjected to several tests. The cross-wires of the instrument were first replaced by a piece of tin-foil pricked full of holes; then, the instrument being directed towards the sky, a photograph of the pin-holes was taken on a plate 15 inches square. Soon after, at the suggestion of Professor Stokes, the tin-foil was replaced by a piece of silvered glass on which various dots and crosses had been scratched. This proved to be better than the pricked tin-foil, because there was no reflection from the sides of the holes. To get the best definition, it was found necessary to insert a quarter-inch stop between the two lenses of the secondary magnifier.

A series of experiments were also made with the view of testing the performance of the 6-inch photographic object glass. The lens was fixed at one end of the long wooden tube which was made for the Eclipse Expedition of 1886.

The tube was mounted on Mr. Lockyer's 6-inch equatorial in place of the ordinary telescope tube. In the preliminary tests, the object glass was directed to a bright star and the image photographed; the telescope clock was stopped so that when the plate was developed there was a fine black line instead of a mere speck, as there would have been if the clock had been allowed to drive. Usually several exposures were made on one plate, the focus being altered each time, and the tube slightly moved in declination so that the lines did not overlap.

Afterwards Professor Stokes suggested that the object glass should be covered with a piece of card, out of which there had been cut a sector of 120°, thus leaving one third of the object glass available. This was done and was found very useful. If the image of a star was photographed within the principal focus, the shape of the sector was reproduced. The image at the focus was of course a point, and on the outside of the focus the image was again a sector-shaped one. Commencing about an inch within the focus, several exposures were made on one plate, the back being moved out a little each time, and the clock being allowed to stand for about half a minute between every two successive exposures. In this way the position of the best focus was determined.

These experiments were going on for about ten weeks, the results in all cases being submitted to Professor Stokes for examination.

During the summer many experimental photographs of the sun have been taken, but so far the results are not very promising.

(4.) *Spectroscopic Observations.*

a. Sun-spot and Prominence Spectra.

By means of one or other of the equatorials, the spectra of spots are examined as frequently as possible, and occasionally a search is made for prominences. This work has been going on regularly since 1879.

Until quite recently (July 1887) the results bear out those results obtained in the previous 700 observations; with the approach to the minimum spot period, the iron and other metallic lines are gradually becoming more and more affected, while the lines of unknown substances are disappearing from among those most widened. The apparent disagreement of the July observations is probably due to the fact that in that month there was a short revival of spot activity.

Up to August 1885, 700 observations of spots had been made, and these have been reduced and the results published.* For a short account of the results, see Spectroscopic Phenomena of Sun-spots, page 8 of this Report.

Since August 1885 150 observations have been made. These have since been reduced, but have not yet been published.

The results are almost perfectly continuous with those already referred to.

Photographs of the spectra of sun-spots and prominences have been taken with a Rutherford grating. The spectroscope was attached to the eye-end of the 6-inch equatorial, and an image of the spot or prominence was formed on the slit by the object glass. On one side of the grating was the camera, and on the other side a small observing telescope, so that the spectrum could be observed whilst being photographed. The whole spectroscope was provided with a fine adjustment independent of the motion of the telescope; in this way any inequality in the motion of the clock could easily be corrected.

It was found, however, that the spot spectrum could only be focussed over a small region.

The spot spectra showed some of the lines widened, and occasionally H and K were reversed.

The prominence spectra sometimes showed H and K reversed, sometimes K alone. No metallic lines were photographed, probably because the photographs were taken at a period of quiescence.

A series of experiments has also been made on the spectra of the arc of a Siemens's machine. It was shown that not only was there a separation of the lines of different elements at the two poles, but that in some cases one set of lines would appear at one pole while other lines of the same metal were seen only at the opposite pole. Other phenomena were also observed and recorded, such as the inverse appearance of lines, in some cases one set of lines being seen alone, in other cases other lines of the same metal appearing by themselves. The various appearances of lines during reversal were also examined.

b. Fractionation Experiments.

Experiments have been made in conjunction with Professor Crookes on the fractionation of some chemical substances.

* Proc. R.S No. 224, 1886.

The substances experimented upon were the nitrates of calcium, magnesium, and iron.

The original nitrate was fused at a red heat until brown fumes were given off, the nitrate being thereby partially decomposed into oxide. The soluble portion was dissolved out with boiling water and separated from the insoluble portion by filtration. The filtrate was evaporated to dryness and called (+1); the residue was washed out and dissolved in nitric acid, evaporated to dryness, and caled (−1). Each of these components, (+1) and (−1), was treated in the same way as the original substance, and gave respectively (+2) plus the original and (−2) plus the original substance. This process was repeated on (+2) and (−2), and (+3) and (−3) were obtained. In the case of calcium the process was carried to (+11) and (−11), magnesium to (+16) and (−16), and iron to (+8) and (−8).

So far, however, no notable differences between the spectra of the (+) and (−) have been observed.

The work has been temporarily discontinued in order that other work might be proceeded with, but will be resumed as soon as convenient.

c. *Oxy-hydrogen Flame Spectra.*

The spectra of most of the metals at the temperature of the oxy-hydrogen flame have been mapped. A Steinheil spectroscope with four prisms was used, and comparisons were made with spark spectra.

The greatest difficulty attending these observations is that of feeding the flame with the substance under examination. The usual method of introducing the substance into the flame on the end of a platinum wire cannot be employed as platinum fuses at the temperature of the oxy-hydrogen flame. For the spectra of iron and copper, fine wire gauze was found to give the best results, as it was easily pierced by the flame and touched the flame on all sides. Most of the other substances were made into a paste and burnt on copper gauze, the lines of copper being easily separated from those belonging to the substance under examination.

In several of the more important cases, photographs of the blue and violet parts of the spectra were taken.

The observations are important as being the spectra of the metals at a temperature intermediate between that of the Bunsen flame and that of the electric arc.

The number of lines of any one substance in the flame spectrum is very much smaller than the number in the arc

or spark spectrum. Thus between wave-lengths 5,100 and 5,500, Ångström records 92 iron lines and Thalen 45; the flame spectrum only contains 8 lines. for the same region. Similarly, copper gives 1 line where Ångström maps 4.

d. Spectra of Carbon Compounds.

An extensive series of experiments have been made on the spectrum of carbon. Since the commencement of the research in 1880 over a thousand photographs of the spectra of various compounds of carbon under different conditions of temperature and pressure have been obtained; of these between two and three hundred have been kept as reference photographs.

The general method employed for obtaining the spectra has been to use flames, or to enclose the gases or vapours in glass tubes provided with platinum points, and to illuminate them by electric discharges from an induction coil.

Different kinds of tubes were used, giving spark discharges varying in length from a quarter of an inch to twelve inches, and in diameter from an inch to one fortieth of an inch. The tubes were usually of a compound form so that different conditions could be obtained without the necessity of charging the tube each time. The end of the tube nearest to the spectroscope was provided with a clear bulb, so that when placed in a line with the collimator, light from every part of the spark passed through the slit.

One end of the tube was connected with a Sprengel pump, and the other with an apparatus for preparing the gas or vapour the spectrum of which was to be examined. All the joints and stop-cocks were made perfectly air-tight by surrounding them with mercury and glycerine.

The whole apparatus was first exhausted as far as possible, and was then filled with gas. This was again pumped out and the tube re-filled, and so on until the gas was perfectly free from air. Whilst this process of washing out was going on the tube was kept constantly heated, so that air and moisture could not adhere to it. Photographs were usually taken during the process of purification in order to ascertain the effect of a small quantity of air or other residual gases upon the spectrum.

When flames were used, the jet was placed about two feet from the slit and an image was focussed on the slit by a lens. The spectroscope employed was one by Hilger, in which the collimator is about 5 feet long, and the camera adapted for quarter plates. As a rule, only one prism was used.

Besides the photographs, a regular series of eye observations have also been made, so that there is a complete record of the whole spectrum.

The general result of these experiments shows that the same compound gas under varying conditions of temperature and pressure usually gives widely differing spectra. The spectrum gradually changes from one of flutings to one of lines as the tension, and probably the temperature, of the spark is increased. The pressure of the gas remaining constant an increase in the length of the spark is accompanied by increased tension, and lines appear in the spectrum. Similarly, the length of the spark remaining constant an increase of pressure is accompanied by an increased tension, and a decrease of pressure by a decrease of tension. Variations of spark conditions are also obtained by the use of a Leyden jar or a jar and air-break. A gas giving a fluted spectrum when the jar is not used may give a line spectrum when the jar is introduced into the circuit, or if the pressure be such that a fluted spectrum is obtained with the small jar, a large jar may break it up into lines. The photographs were taken with the gases at gradually increasing or decreasing states of tension, by combining different pressures with different lengths and strengths of sparks.

The compounds of carbon to which attention has been directed include cyanogen, marsh gas, acetylene, benzene, carbonic acid, carbonic oxide, carbon tetrachloride, alcohol, and petroleum. The different compounds vary greatly in their behaviour when subjected to the same temperature; thus, the temperature at which benzene gives a certain set of carbon flutings is insufficient to give the same set from carbonic oxide, and the temperature at which carbonic oxide gives flutings might be sufficient to give the line spectrum from benzene. These facts are mentioned to show the intricacies involved.

Several groups of flutings which have been attributed by other observers to particular compounds of carbon, have been found common to the spectra of all the compounds experimented upon, in the absence of well-known groups belonging to the particular compounds, and it is therefore probable that such groups have their origin in carbon itself.

The wave-lengths of the lines and flutings were determined by comparisons with the known spectrum of the electric arc.

Several sets of carbon flutings occur in the spectrum of the electric arc, and these have also been photographed and mapped. It may be remarked that at the tip of the flame which often surrounds the negative pole, especially when the

current is being started or broken, there occur three sets of flutings which have not been recorded by other observers. Unlike those occurring in the arc spectrum, these flutings shade off towards the red.

c. Spectra of Stars, with special reference to Carbon.

Having obtained some two or three hundred reference photographs of carbon spectra under known conditions of temperature and pressure, we are now prepared to undertake an investigation of the nature of the carbon which is known to exist in many of the stars.

It is proposed to get comparisons of the star spectra with the spectrum of a known carbon compound enclosed in a Geissler tube. The Geissler tube will be placed in front of the object glass and a small lens will be introduced to render the rays of light from the tube parallel to each other. The Geissler tube will thus be focussed on the slit at the same time that a star is focussed. The tube being placed parallel to the slit, the spectrum of the carbon compound enclosed in it will have a width equivalent to the length of the slit. The image of the star will be allowed to travel over only a small portion of the slit. In this way a double spectrum will be obtained—the spectrum of the star superposed upon the much wider spectrum of the Geissler tube. Any coincidences will be marked by an increased intensity in the flutings composing the spectrum of the Geissler tube where crossed by the star spectrum.

The preliminary trials of this method have not proved very satisfactory, probably because the object glass of the telescope did not give a photographic image on the slit. The spectroscope employed was one in which the prism was made of Iceland spar.

Experiments have also been made with the view of using a diffraction grating for star spectra. The grating, ruled on silvered glass, was placed inside the principal focus of the object glass, so that when the telescope was pointed to a star, the star was focussed after reflection from the surface of the grating. In this way the spectrum could be obtained without the use of any lens except the object glass. The photographic plate was placed at a distance from the grating equal to the distance of the grating from the principal focus. The spectrum thus obtained, however, would be without width; the necessary width was obtained by adjusting the grating so that the lines were parallel to the equator of the telescope, and allowing the clock to travel a little too slow or a

little too fast. The star thus had a motion relatively to the grating. The spectra obtained, however, were deficient in definition, probably because, as before, the object glass did not form a photographic image.

f. Spectra of Metals at different Temperatures.

Observations have been made on the spectra of the metals at the temperatures of the oxy-hydrogen flame, electric arc, quantity coil, and intensity coil, to endeavour to find out the origin of the differences observed between the lines of the same chemical substance here in sun-spots and at Rome in prominences.

As an example, the effect of temperature on the spectrum of calcium may be stated:—(1.) At a low temperature we get a spectrum of calcium which contains no lines whatever in the blue; (2) when the temperature is increased - the temperature of a Bunsen burner is sometimes sufficient—we get a line in the blue at wave-length 4226·3; (3.) when we pass from a Bunsen to an electric lamp we get this blue line intensified, and at the same time we get two new lines in the violet, named H. and K.; (4.) using a still higher temperature in the arc, we thin the blue line, and at the expense of that line, so to speak, we thicken the two in the violet, so that the latter equal the blue line in thickness and intensity; (5.) passing to a large induction coil with a small jar, we make the violet lines very much more prominent; (6.) and using a larger induction coil and the largest jar we can get, we practically abolish the blue line and get the violet lines alone.

(5.) *Work published (Spectroscopic).*

The following is a list of papers prepared by Mr. Lockyer, and, at the desire of the Committee, communicated by him to the Royal Society since the submission of the Committee's last Report.

"Note on the Recent and Coming Total Solar Eclipses." Received 17th November 1882.

"A New Form of Spectroscope." Received 5th December 1885.

"Further Discussion of the Sun-spot Spectra Observations made at Kensington." Communicated to the Royal Society by the Solar Physics Committee. Received 5th May 1886.

"Further Discussion of Sun-spot Observations made at South Kensington." Received 8th January 1887.

"Researches on the Spectra of Meteorites." Received 4th October 1887. Addendum. Received 15th November 1887.

"Suggestions on the Classification of the various Species of Heavenly Bodies." (Bakerian Lecture.) Received 21st March 1888.

"On the Spectra of Meteoric Swarms in the Solar System." Received 22nd November 1888.

"On some Effects produced by the Fall of Meteorites on the Earth." Received 22nd November 1888.

"Suggestions on the Origin of Binary and Multiple Systems." Received 22nd November 1888.

"On the Spectrum of Saturn's Rings." Received 7th February 1889.

"On the Spectra of Meteor Swarms." (Group III.) Received February .

APPENDIX I.

Government Eclipse Expedition, 1883.

Instructions to Observers.

1. In case of any difficulty at any port either on going out or coming home, Mr. Lawrance to hand Foreign Office letter herewith to the British Consul at that port and ask his assistance.

2. On joining the American party Mr. Lawrance and Mr. Woods to report themselves to the astronomer in charge of the expedition and to hand him the accompanying letter, taking his advice and following his instructions with reference to the transference of the instruments to the U.S. ship of war.

3. On arriving at the place of observation the instruments to be erected on a site to be chosen by the American astronomer in charge.

4. Packing cases to be reclosed up as far as possible and to be protected from damage and the weather. Care to be taken not to damage tin cases.

5. The gratings to be kept together and special precautions to be be taken with regard to them, as also with the silvering of the siderostat mirrors. Mr. Lawrance to give special attention to this point.

6. For as many days as possible before the eclipse all the instruments to be arranged as during the eclipse, and from 11.28 a.m. local mean time to 11.48 local mean time, complete rehearsals of all the observations intended to be made during the eclipse to be most rigidly carried out.

7. A statement of the days on which these rehearsals have been made to be given in the report of the operations.

8. If the aforesaid times derived from Mr. Hind do not agree with the times determined by the American astronomers, the instructions of the astronomer in charge are to be taken.

9. Instruments to be focussed and trial plates taken, if possible, at least two days before totality. These trial plates to be carefully preserved.

10. The rehearsal on the day before the eclipse should be a complete rehearsal, with photographic plates exactly as during the eclipse itself, and these plates to be developed at once and brought home.

11. The observers should confer with the American astronomer in charge regarding time signals before and after totality.

12. If additional observing power can be obtained from the American party, the additional observers to be trained to obtain photographs with the photoheliographs, and if desirable, the time-table for that instrument to be handed over to them, they being placed in entire charge of that part of the operations.

13. If such assistance cannot be afforded, then, if the photoheliograph programme cannot be carried out in its entirety, the large pictures to be alone attempted.

14 Special attention to the rating of the clocks, including the eclipse clock and siderostat, to be given at least three days before the eclipse.

15. A quarter of an hour before totality, clocks to be wound, and caps and stops, which had hitherto been used to diminish the amount of light, to be removed if necessary.

16. The timekeeper should be asked to give these instructions in a loud voice, as experience has shown that they are apt to be forgotten.

17. In the observations and adjustments during the eclipse no deviations from the time-table and adjustments to be made except after consultation and with the approval of the American astronomer in charge.

18. The clockwork of the integrating spectroscope to be so adjusted that the plate will fall through 1 inch in 8 minutes.

19. The distance of plate from concave grating to be that given by Captain Abney for vertical distortion.

20. In equatorial the slits to be parallel and vertical in the meridian and their centres lying on the same part of the sun.

21. All the slits to be $\frac{1}{500}$ in. = No. 2 on Captain Abney's screw, with the exception of the integrating spectroscopes which should be $\frac{1}{250}$ in.

22. At some convenient time, say 100 seconds, near the middle of totality the slits of equatorial to be brought to the point of re-appearance,

23. The plates to be developed and copied at the first convenient time after the eclipse is over.

24. Half the positives and half the negatives to be handed to the British Consul at Callao, to be forwarded to the Foreign Office for transmission to the Science and Art Department by the next mail after that by which the observers leave.

25. On arrival at Callao a cypher telegram to be despatched to Secretary, Kensington Museum, London, giving the results obtained with each instrument and stating any other matter of importance.

26. Great care to be taken in replacing the instruments after the eclipse. Tin cases to be reclosed.

27. A detailed report to be prepared before arrival at Callao of the general results, to be posted to me immediately on arrival at Callao, in case of any delay en route.

28. If a convenient opportunity arises for sending this report from the Marquesas, this course to be followed as well as the other.

29. It is to be understood that the records of the eclipse are the property of the British Government.

30. In case no pictures are taken with the small photoheliograph, Mr. Lawrance is requested to ask the American Astronomer in charge for an oriented positive of the corona to facilitate reference here.

31. Mr. Lawrance is empowered to hand to the American astronomer in charge positives of any of the pictures taken by the English party which he may require for a similar purpose, and to obtain a receipt for them.

W. Spottiswoode, P.R.S.

J. Norman Lockyer,
16th Feb. 1883.

Code for Cypher Telegram.

Very good.	*Good.*	*Indifferent.*	*Bad.*	*Very bad.*
Bad	bell	bird	bog	bust
Can	cent	cinder	cow	cut
Day	den	dip	dog	dust
Far	fetch	fig	frog	fun
Gas	get	gill	gold	gum
Hall	hen	hit	hold	hunt
Kappa	keg	king	Koch	Kuhne
Lamb	length	light	lot	lump
Mad	mess	mint	most	muff
Nag	nest	night	now	nut
Pan	pelt	pig	port	pull
Rag	rent	right	rot	rust
Sap	sell	sing	sort	sum
Tar	tent	tin	told	tug

B = 6 prism on equatorial.
C = double grating on equatorial.
D = dense prism on portion of 6-inch equatorial
F = Integrating Hilger.
G = Red end slit.
H = Red end prismatic camera.
K = 1st order blue Rowland.
L = 2nd ,, ,, ,,
M = 4-inch photoheliograph.
N = small ,,
P =
R =
S =
T =

Adjustments.

B. 7-prism spectroscope.
F. line in centre of plate.

C. Flat grating spectroscope.
First order.
F. in centre of plate
Second order.
F. in centre of plate.

D. Dense prism.
F. in centre of plate.

F. Integrating Hilger (Flash).
G. in centre of plate.

G. Red end slit.

H. Red end prismatic camera.

K. First order blue. Rowland.
F. in centre of plate.

L. Second order blue. Rowland.
H. in centre of plate.

M. 4-inch photoheliograph.
See that sun runs along horizontal wire.

N. Small photoheliograph.

Form for recording Observations.

Time.	Siderostat.				
	Hilger.	Rowland Grating.		Prismatic Camera.	Slit Spectroscope 2 prism.
		1st Order.	2ndOrder		
Minutes.					
10					
9					
8					
7					
6	ref. spectrum 30 secs.				
5					
4					
3					
2					
Seconds.					
60					
40		expose.	expose.		
30					
20		expose.	expose.		
3					
2	expose and start clock.				
1					
Totality		expose.	expose.	expose col. plate.	expose.
300					
290					
280					
270					
260					
250					
240					
230				shut.	
220				expose gel. plate.	
210					
200		expose.	expose.		
190					
180					
170					
160					
150					
140					
130					
120				shut.	
110				expose col. plate.	
100					
90					
80					
70					
60					
50					
40					
30					
20					
10					
Just before end		expose.	expose.	shut.	shut.
Seconds.					
1					
2					
3					
4		expose.	expose.		
5					
10		expose.	expose.		
15					
20					
30					
40					
50					
Minutes.					
1		shut.	shut.		
2	shut.				
3					
4					
5					
6					
7					
8					
9					
10					
					2 sec.

Equatorial.				Photoheliographs.	
prism F.	Grating. F. Red 1st Order.	Grating. F. Blue 2nd Order.	¼-inch Slide. Dense prism F.	Large Photo-heliograph.	Corona Camera.
expose.	expose.	expose.			
			expose.		
			expose.		
			expose.		
			expose.		
			expose.		
expose.	expose.	expose.	expose.		
			expose.		
			expose.		
	run ¼-inch.				
expose.	expose.	expose.	expose.	expose.	expose 1 sec
					expose 20 sec.
					expose
			expose.	expose	
					shut.
					expose 3 sec
				expose.	
					expose 10 sec
					expose 2 sec.
expose.	expose.	expose.	expose.	shut.	
	run ¼-inch.				
	expose.	expose.	expose.		
			expose.		
expose.	expose.	expose.	expose.		
			expose.		
			expose.		
shut. 10 sec.	shut. 10 sec.	shut. 10 sec.	shut. 1 sec.	run.	run.

APPENDIX II.

Note by Professor Tacchini on Eclipse of 1886.

Je crois que la question de la planète intermercuriale n'est pas resolue d'une manière satisfaisante. M. Holden et M. Palisa ont fait, à Caroline, tout ce qu'il était possible avec une lunette parallatique, oui ils ont accompli très-bien la partie dont ils étaient chargés, mais on ne peut pas conclure pour cela que la planète ou les planètes n'existent pas entre Mercure et le Soleil, car un examen avec lunette pendant une éclipse, même de 6 minutes, ne peut se faire que pour un nombre très-restreint des étoiles assez brillantes et par conséquent la découverte obligerait à admettre que la planète est d'une certaine grandeur pour être tout de suite aperçue dans des conditions aussi exceptionnelles pour l'observateur. Donc il faut étudier la manière d'employer uniquement la photographie pour cette recherche et avec plusieurs instruments. Après il y a la question de la couronne et des panaches, car les photographies prises jusqu'à présent ne valent pas grand'chose: il faudrait partager les opérations et employer une machine pour chaque recherche à faire. Les protubérances blanches que j'ai vues à Caroline ne sont indiquées dans aucune photographie: seulement à l'observatoire de Washington, avec M. Harkness, parmi ces nombreuses plaques, nous avons trouvé quelques photographies seulement qui montraient quelques indices de la chose; il y a donc beaucoup à faire encore pour obtenir de bonnes épreuves; aussi les panaches vus avec ma lunette n'ont rien à faire avec les photographies de M. Janssen, et M. Janssen aussi m'a dit que la chose est bien différente. Et même pour la photographie des spectres, il y a raison de prétendre un travail mieux défini, c'est-à-dire on doit chercher à faire des photographies qui donnent vraiment les spectres isolés tant qu'il sera possible, de protubérances, des panaches, de la couronne, etc.; sans oublier les observations directes, mais faites avec des instruments propres et avec un programme bien défini. Pour arriver à faire tout il faut beaucoup de monde, de bons instruments et une éclipse d'une durée assez longue. L'éclipse aura lieu en 1886. L'instrument et les observateurs ne peuvent être fournis par une seule nation. On pourrait donc proposer une société pour l'éclipse de 1886. En 1884 définir le programme, 1885 les expériences à faire, et en 1886 aller observer l'éclipse.

P. TACCHINI.

APPENDIX III.

TABULATION OF SUN-SPOT DATA.

(1.) *Report of the Astronomer Royal and Professor Balfour Stewart on the best Method of tabulating the Sun-spot Data now available.*

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1. In a Catalogue of solar pictures and photographs forming an Appendix to the Report of the Solar Physics Committee will be found a nearly complete specification of the material available for the purpose of carrying into effect the first recommendation of that Report, which advocates the importance of collecting and publishing the existing information regarding sun spots.

2. In order to render the reduction and publication of this back work as useful as possible, two things would appear to be necessary.

In the first place the record should be rendered as complete as possible by means of the contributions which the directors of the various solar observatories have kindly undertaken to give; and, *in the second place,* the Committee should endeavour to obtain a numerical estimate of the accuracy of the various contributions which they hope to receive.

3. For this latter purpose it will be desirable to regard the Kew series while it lasts, and after it the Greenwich series, to both of which easy access may be had, as standards with which a certain number of comparisons should be made in the case of each observatory. As regards the estimate of accuracy of the results obtained at these standard observatories, it is to be remarked that both in the Kew and Greenwich series there is a large number of days on which two photographs have been measured, and a simple comparison of the results would give the desired information. Thus each solar observatory will be asked to contribute information for certain days when there was no photograph taken at Kew or Greenwich; and also a small additional amount of such information for certain days when photographs were taken at Kew or Greenwich with the view of comparison with these pictures.

As there are several solar establishments it is hoped that the call made upon any one of them will not be found very burdensome.

4. We would recommend that in future measurements the spot should be taken as the unit rather than the group, and that the area and heliographic longitude and latitude of each spot (or cluster of small spots) be determined for every day for which a photographic record exists.

This substitution of the spot for the group will entail comparatively little additional labour in calculation, inasmuch as all determinations of the areas and positions of groups are derived by bringing together the corresponding measurements of their spot components. The published results would under this system occupy, no doubt, a greater space than if the group were adopted as the unit; but the possibility of deducing important scientific conclusions regarding the relative behaviour of the components of a group would be preserved, while it would entirely disappear if the group were taken as the unit.

5. Further, it appears to us desirable that the daily areas of faculæ (accompanied by rough measures of position-angles and distances from the sun's centre) should also be determined.

6. In the tabulation of results it is desirable to keep to one uniform system, and we would therefore recommend that the form employed in the Greenwich Photographic Results be adopted.

7. The following table shows the number of days on which photographs were taken at Kew or Greenwich, the number of days on which photographs taken elsewhere are available to fill the gaps in the Kew or Greenwich series, and the total number of days in each year.

NUMBER of DAYS on which PHOTOGRAPHS are available.

Year.	Kew.	Other Observatories.*	Total.
1863 - -	131	62 E.	193
1864 - -	161	44 E.	205
1865 - -	146	47 E.	193
1866 - -	158	57 E.	215
1867 - -	144	63 E	207
1868 - -	140	45 E.	185
1869 - -	168	48 W. & E.	216
1870 - -	218	59 C., W., & E.	277
1871 - -	205	65 C., W., & E.	270
1872 - -	37	230 C., W., & E.	267

* In this table E. denotes Ely; W., Wilna; C., Cambridge, U.S.; Ma., Mauritius; Me., Melbourne; Mo., Moscow

Year.	Greenwich.	Other Observatories.	Total.
1873 - -	64	178 C., W., & E.	242
1874 - -	163	63 C , W., & E.	226
1875 - -	161	128 C., W., Ma , Me., Mo.	289
1876 - -	163	150 C., W., Ma., Me , Mo.	313
1877 - -	169	117 C., W., Ma , Me., Mo.	286

We now proceed to discuss the various series of observations.

Schwabe's Observations.

8. In the Catalogue already referred to there will be found recorded under their appropriate dates the total spotted area for each day when Schwabe took a sun picture, these results extending without interruption from the beginning of 1832 to the end of 1853. Besides this continuous series for which Schwabe was the sole observer, it will be found from the Catalogue that certain pictures of Schwabe's are coincident in point of time with certain pictures of the Redhill and of the Kew series. Means thus exists for determining the numerical accuracy of Schwabe's pictures, and it seems desirable that such a determination should be made.

Redhill Series.

9. In his publication entitled ' Observations of the Spots on the Sun, from November 9, 1853, to March 24, 1861", Carrington has given a detailed account of his method of observation, and has exhibited the heliographic positions of the various spots observed by him on the sun's surface.

Carrington's pictures were accurate sketches from eye observation, and not photographic records. Nevertheless, as there are a few days on which pictures by Carrington, and photographs at Kew were taken simultaneously, it would be desirable to endeavour to obtain from these simultaneous records a numerical estimate of the value of Carrington's observations.

10. The positions given by Carrington are not those of the centres of mass of the various groups, but of the individual members of each group. It will therefore be necessary to obtain the former from the latter. This may be easily done,

inasmuch as sufficiently extensive measurements of the areas of each member of each group have been made by Mr. De La Rue and his colleagues—indeed the materials for obtaining the mean latitudes of each of Carrington's groups are very nearly complete and little more will be necessary than to obtain the mean longitudes.

The areas of the various spots have been measured by Mr. Loewy, and a selection of these should be remeasured in order to verify the accuracy of Mr. Loewy's determinations.

Mr. Howlett's Observations.

11. The Rev. F. Howlett has made a long series of careful drawings of sun spots. The regular series began in 1859, and was carried on methodically for about eight years, and drawings were occasionally made from thenceforward to the present time. The spots or groups of spots were drawn on a screen on a large scale (1 inch = 1′ in the earlier drawings, and = 30″ in the later), an image of the sun being projected on the screen. The features of the spots or groups were thus depicted; and on account of the largeness of the scale the spot or group was cut out from the screen, and is alone preserved on the large scale; but drawings were made almost simultaneously on a smaller scale (1 inch = 9′ 40″) giving the positions on the disc of the spot drawn on the large scale. The drawings made from 1859 to 1874 have been presented to the Royal Astronomical Society.

The Ely Photographs.

12. These began and ended nearly two years later than the Kew series. They were taken by the late Canon Selwyn, whose widow gave the pictures to the Royal Society, in whose possession they now are.

The day of observation of each picture is known, but the exact hour is not recorded, nevertheless it is believed that information on this point exists in the possession of the Solar Physics Committee.

13. There are a good many cases in which a picture was obtained at Ely but not at Kew. In these it would be of great importance to obtain the areas of the various groups recorded in the Ely pictures.

14. Unfortunately there are no fiducial lines in the Ely pictures, but it may nevertheless prove possible to obtain from these pictures approximate determinations of the position of certain groups which might be better than not knowing their

positions at all. This information would only be of service for such groups as are not recorded at all in the Kew pictures, if there be any such. For these reductions it will be necessary to obtain the loan of the Ely pictures from the Royal Society.

Kew Photographs.

15. Mr. De La Rue has obtained determinations of the areas of each Kew group of sun-spots. He has likewise caused a certain proportion of these areas to be remeasured. This will give the means of estimating numerically the precision of these area determinations.

16. Mr. De La Rue has recently presented to the Royal Society the heliographic positions of each spot of each Kew group along with a classification of these into ten relative magnitudes. It will be necessary for the purposes of the Solar Physics Committee that from this MS. the heliographic positions and relative magnitudes of each individual member should be brought together for each sun-spot group, then weighting each member according to its relative magnitude, the positions of the centres of mass of whole groups might be determined with sufficient accuracy to suit the objects of the Committee.

It would be desirable to remeasure and recalculate the positions of a certain number of the Kew groups (if this has not been done) in order to be able to estimate numerically the precision of these determinations.

Photographs of other Observatories.

17. It frequently happens that on days when no picture can be taken at Kew or Greenwich pictures have nevertheless been taken at other places.

It will be necessary in such cases to make use of the good offices of the directors of these observatories in order to render the catalogue complete.

The most suitable principle in making such applications would be not to lay an excessive burden upon any one institution, but to distribute the work required in an equable manner amongst them all.

18. It would, however, be extremely desirable for those days which are blank for Kew or Greenwich to have measurements of areas from two different stations if possible—more than two would be superfluous.

With regards to positions the measurements of these from a single station would suffice.

19. The method which we would propose for obtaining these measurements and securing their accuracy is best illustrated by an example. Referring to the catalogue of Solar Photographs for 1871, it will be found that on July 10th pictures were taken at Kew and Wilna. On July 11th and 12th pictures were taken at Wilna but not at Kew, while on July 13th pictures were taken at Kew and Wilna. In this case the Director of the Wilna Observatory might be asked for the areas and positions of the various groups of spots for the four days July 10th, 11th, 12th, 13th, the determinations for July 11th and 12th being required to fill up gaps, while those for July 10th and 13th would be necessary for comparison with nearly simultaneous Kew pictures, one object amongst others of this comparison being that by its means a numerical estimate of the precision of the Wilna determinations might be obtained.

Furthermore, to enable the Director of the Wilna Observatory to identify the groups, copies on tracing paper or otherwise of the Kew pictures of July 10th and 13th would be sent to him.

But it would probably not be necessary on all occasions to request from the foreign observatory a remeasurement of pictures common to Kew, such as those of July 10th and 13th, in this illustration. It would, however, always be necessary to send to the foreign observatory sketches or tracings of such common pictures.

20. It is apparently unnecessary that the various observatories should be troubled regarding details of their reductions, inasmuch as approximate accuracy is all that the Solar Physics Committee desire, and the standard which would satisfy the Director of a Solar Observatory would satisfy the Committee.

Furthermore the proceedings described in Arts. 18 and 19 of this report would probably be a sufficient safeguard against the occurrence of mistakes.

21. Should it be very inconvenient to an observer to give the heliographic positions of each group for each day for which these are asked, it seems possible that two determinations of these, as far apart as possible in the lifetime of each group, might be sufficient to serve many of the purposes of the Committee, nevertheless it is desirable that the catalogue of such positions should, if possible, be complete.

Greenwich Photographs.

22. After the Kew series ceases it is proposed that Greenwich should become the standard station.

The areas and positions of the various groups of the Greenwich series are already published.

The Astronomer Royal would undertake to furnish such tracings of certain of the Greenwich pictures as it may be necessary to send abroad for the purposes herein indicated.

Suggested Mode of Procedure.

23. It is suggested that the following steps should be taken:—

(1.) The Committee should communicate with the Directors of Solar Observatories, sending them a copy of this Report, and requesting from them a list as before of their sun pictures between the end of 1877 and the beginning of 1882. A further communication should then be addressed to each Director asking him to supply the areas and positions of sun spots and faculæ from the photographs in his possession for days specified in accordance with paragraph 15 of this Report; or in case of his not being able to undertake the work to supply the Committee with materials for doing it themselves.

(The position-angles and distances from the sun's centre of spots and faculæ may be measured with sufficient accuracy by means of a glass plate ruled with concentric circles at a distance of $\frac{1}{20}$ of the sun's radius apart, every fifth circle being thicker, the 18th circle being divided into degrees, with cross lines through the centre to the four cardinal points 0°, 90°, 180°, and 270°.)

(2.) The Indian photographs from the beginning of 1878 to the end of 1881 should be measured in duplicate for those days on which there are no photographs at Greenwich. This work has been commenced by Mr. Lawrence. It will probably occupy the whole time of one person for 15 months.

(3.) Application should be made by the Committee for the loan of the Kew series of photographs, of the Ely series, of Carrington's original drawings, and of the measures of areas from these drawings made by Messrs. De La Rue, Stewart, and Loewy, with a view to a remeasurement either in whole or in part of the areas of spots and the measurement of faculæ. This work might be commenced after the completion of the measurement of the Indian series.

(2.) *Indian Photographs.*

The Indian photographs for dates subsequent to Jan. 1, 1882, have been forwarded to Greenwich for reduction, and already the reductions have been published in the Greenwich photographic results as far as the end of 1887.

The arrangements at Greenwich, however, would not allow of the reduction of the Indian photographs anterior to 1882. An instrument similar to the one in use at Greenwich was therefore purchased by the Committee, and the reductions were placed under the direction of Professor Lockyer. Only those photographs which fill gaps in the Greenwich series have been measured. Of these, there are 41 for the year 1878, 23 for 1879, 152 for 1880, and 160 for 1881. All these have been measured and the reductions are now ready for publication.

Silver prints of the Indian and Mauritius photographs are mounted and bound in volumes, convenient for reference.

(3.) *Mauritius Photographs.*

There are photographs for 48 separate days from the Royal Alfred Observatory, Mauritius, dating from Feb. 3, 1878, to Sept. 17, 1882. All these contain spots and fill gaps in the Greenwich-Indian series. Of these, however, those for 1878 and 1879 have no cross-wires. The dates are as follows:—

1878. Feb. 3, 5. Sept. 5. No cross-wires.

1879. April 16, 20, 21. July 11, 12, 14, 15, 16. Aug. 11, 28, 31. Sept. 5, 7. Oct. 11, 14, 17, 19. Nov. 8, 9, 10, 11, 16, 17, 29. Dec. 1. No cross-wires.

1882. Jan. 10, 11, 12, Feb. 9, 21. April 29. June 18, 19. July 4, 6, 30. Aug. 1, 5, 7, 13, 19, 28. Sept. 10, 14, 17. With cross-wires.

All the photographs with cross-wires (1882) have been measured and reduced and the copy for press prepared.

(4.) *Melbourne Photographs.*

Since the end of 1877 (the date up to which the list in the last report was made) 1,261 photographs have been received from Melbourne. Of these, 159 are for 1878, 176 for 1879, 170 for 1880, 190 for 1881, 204 for 1882, 154 for 1883, and 203 for 1884. Many of them, however, contain no spots.

The following is a list of the dates of the photographs containing spots which will fill gaps in the Greenwich-Indian-Mauritius series:—

1878. Jan. 25, 26. June 1, 5.
1879. Feb. 15. April 22, 23. May 9. July 1, 3, Oct. 8.
1880. Jan. 9. Feb. 10, 14, 16. Mar. 22. April 22. June 14, 25. July 6, 16, 17, 28. Aug. 6, 16. Nov. 18. Dec. 28.
1881. Feb. 22. Mar. 26. June 5. July 7, 20, 23, 27. Sept. 3. Nov. 30. Dec. 29.
1882. Jan 31.
1883. Jan. 24. July 17, 18, 23. Aug. 4, 6, 29. Sept. 6. Dec. 1, 3, 31.
1884. Feb. 19, 28. Mar. 4, 13. May 20. June 2, 5, 18, 19. July 1, 6, 7, 13, 15, 16, 23. Sept. 1, 14, 26, 29. Oct. 1, 24. Nov. 27, 30. Dec. 23.

The measurements and reductions have been completed for all these, with the exception of five (1883, July 17, 18, 23, Aug. 4 and 6), which seem to have been wrongly dated. The mistake could probably be rectified by comparison with the Greenwich—Indian Series. These have been omitted from the reductions.

In these photographs the cross-wires are at angles of 45° to N. and S. points.

(5.) *Sydney Photographs.*

There are 146 photographs from Sydney for the year 1881 and 17 for the year 1882. An examination of the photographs and dates shows that five of those for 1881 were taken on days for which there are no other photographs. The dates of these are as follow:—

1881. June 7, July 8, 22. August 31. September 2.

These photographs have only one cross-wire and are all unvarnished. The cross-wire is out of focus and the limb is ill-defined in every case, it has therefore been impossible to make measures of any real value.

(6.) *Lisbon Photographs.*

Since the year 1878, the date up to which the list of photographs was made in the last report, only 12 photographs have been received from Lisbon. The dates are as follow:—

1880. May 30. June 2, 23, 24, 25, 26, 27. Sept. 15, 30. Oct. 1, 2, 3.

Of these only that for June 26 fills a gap in the Greenwich-Indian series. The photographs have only one cross-wire. No information has been given as to the position angle of the wire. An attempt to arrive at it (so as to reduce the measurements) by a comparison of the spots with those on other measured photographs was not successful.

(7.) *The Poughkeepsie Photographs.*

At the request of the Committee, Miss Whitney, of Vassar College, Poughkeepsie, N.S., has kindly offered the Vassar College series of solar photographs for measurement and reduction. The following is a list of the dates of the photographs in this series for which there are no other photographs:—

1872. June 6. Nov. 1, 15. Dec. 7, 10.

1873. Jan. 9, 14, 25. Feb. 14, 20, 22, 25. Mar. 13, 14, 17, 19. Apr. 29. June 18. Oct. 10, 11, 22, 23. Nov. 5, 6, 10, 14, 26, 29. Dec. 6, 15.

1874. Jan. 10, 18, 20, 26. Feb. 12, 14, 17, 18, 20, 26. Mar. 3, 4, 14, 21, 30. Apr. 2. May 3, 10, 13, 14, 17, 23, 28. June 17, 21. Oct. 9, 12, 24, 31. Nov. 10, 14, 19, 26. Dec. 8, 10, 12, 15, 16.

1875. Feb. 1. Mar. 4, 19, 22, 29, 30. Apr. 10, 15. Oct. 22. Dec. 27.

1876. Jan. 21.

1877. Jan. 14. Feb. 9, 13, 15. May 12.

1878. Feb. 6.

1884. Jan. 16. June 9.

None of these have yet been received.

(8.) *Cambridge Photographs.*

Prof. Pickering, of Cambridge, having kindly placed a series of sun-pictures at the disposal of the Committee, a list of those which would fill blank days was prepared. The photographs, 118 in number, for days between Dec. 9th, 1874, and Aug. 31st, 1875, were sent to London last year. They have been measured and reduced at Greenwich. With Professor Pickering's permission, positives of all the photographs have been taken by Sergeant Kearney, R.E., at South Kensington, and these will remain in the hands of the Committee when the originals have been returned.

(9.) *Record of Absence of Spots.*

On some days for which no photographs were obtained either at Greenwich or Dehra Dun, Dr. Meldrum records the absence of spots on the sun's disc. The following is a list of such days:—

1878. Jan. 1, 2, 4, 5, 8, 12, 13, 16, 19, 20, 21, 22, Feb. 2, 9, 10. Mar. 10, 21, 31. Apr. 28, 29. May 5, 7, 8, 11, 12, 14, 15, 19, 20, 21, 22. June 16, 23, 30. Nov. 10, 13, 14, 15, 17.

1879. Jan. 11. Feb. 13, 27. Mar. 2. Apr. 1, 3, 5, 6, 9, 10, 11, 27, 28. May 2, 4, 6, 7, 15, 16, 18. 23, 25, 26, 27, 30. June 1, 2, 6, 7, 10, 12, 13, 16, 19, 21, 22, 23. July 8, 10, 21, 22, 23, 26, 28, 31. Aug. 4, 5, 8, 14, 16, 20, 21, 26. Sept. 9, 11, 14, 17, 18, 19, 20, 21, 23. Oct. 5. 23, 24, 26, 28, 29, 30, 31, Nov. 1, 2, 3, 21, 22, 23, 24, 26. Dec. 7, 12, 13, 14, 15, 26, 27.

(10.) *Days for which there is no Record.*

The following is a list of days (1878-1884) for which there are no photographs and no record of absence of spots:—

1878. Jan. 6, 24, 27. Feb. 4, 7. May 26. June 7. July 7, 14. Aug. 18.

1879. Jan. 12. Feb. 16. Apr. 12, 13, 14. May 8, 11 20. June 8, 15, 26, 29. July 6, 13, 17, 19, 20, 27. Aug. 3, 10, 17, 23, 24, 29. Sept. 12, 28, 29. Oct. 9, 12, 13. Nov. 4, 5, 30. Dec. 25.

1880. Jan. 8, 18. Feb. 8, 30. Apr. 4, 6. June 13. July 1, 7, 18, 25. Aug. 14, 15. Sept. 19. Nov. Dec. 15, 25.

1881. Jan. 2. Feb. 2. June 12, 26. July 10. Aug. 7, 21. Dec. 25.

1882.

1883. Mar. 11. July 30. Aug. 5. Sept. 2. Dec. 30.

1884. Jan. 1. Feb. 3, 17. Mar. Apr. May. June 8. July 21, 22, 29, 30. Aug. 30, 31. Sept. 28.

The Stonyhurst sun-pictures, which are drawn with the greatest possible care, contain records of spots on the following dates:—

1880. Nov. 21.

1881. Jan. 8. April 24.

1882, Jan. 30.

1883. Jan. 20. March 26. July 8, 22. Sept. 11. Nov. 11.

1884. Jan. 26. Mar. 8. April 12, 18. May 10. June 10, 17. July 2, 14, 17, 18, 28. Aug. 19.
1885. Dec. 8.

Spots were noticed, but not drawn, on March 2 and June 19, 1881.

The areas of the spots are all being measured at Stonyhurst Observatory.

(11.) *Large Scale Sun-pictures.*

In view of the presumed superiority of the 8-inch photographs of the sun over the 4-inch, the Indian Government, together with the directors of other observatories possessing photoheliographs on the Greenwich pattern, were requested to revert to the 8-inch photographs.

This arrangement has been adopted by the Indian Government, Mr. Meldrum, and Mr. Ellery.

The regular series of photographs from Dehra Dun, dating from November 11, 1882, are accordingly on the 8-inch scale, and in addition to these 12-inch pictures are taken when the atmosphere is exceptionally clear, or the sun-spots remarkable for number or magnitude.

Those from Mauritius, dating from February 25, 1885, are also on the 8-inch scale.

(12.) *Discussion of the Reductions.*

The results of the reductions of the solar photographs are being carefully investigated at South Kensington with a view of tracing proper motions and distribution in longitude. Curves have been constructed to show graphically the phenomena recorded on the photographs, as far as areas and positions are concerned, for each rotation.

Besides these drawings, the spots are being plotted out on a large white globe, about 30 inches in diameter. The globe is provided with two axes at an inclination of 7° 15′. The meridian circle is divided into degrees and half-degrees. There are two equators, corresponding to the two axes, and these are graduated in degrees and subdivided to 15′. One circle represents the equator of the sun, and the other the ecliptic.

The areas of the spots are represented conventionally as follows, the spots of area smaller than 50 millionths of the sun's visible surface being neglected :—

● - - -	50—200	millionths.
+ - - -	200—500	„
△ - - -	500—1,000	„
⊡ - - -	over 1,000	„

A group is represented as a single spot, the latitude and longitude being taken as the centre of gravity of the group.

In the Greenwich Spectroscopic and Photographic Results for 1886 and subsequent years the areas and positions of spot-groups are collated for the several days on which the group was visible, and the area and mean longitude of the group are formed with a view of facilitating discussions of the changes from day to day in a spot-group and the recognition of those regions of the sun where spots form most frequently.

The following lists, &c. have been prepared in connexion with the work done on the globe :—

1. A list showing the mean areas of umbræ whole spots and facular upon the sun's disc for each rotation of the sun from July 28, 1883, to December 30, 1884.
2. A table showing the history of a group of sun-spots in the southern hemisphere in June 1880.
3. List of spot-groups over 500 in area which are within 7° longitude of each other, and having + latitudes (from 1880 to 1884).
4. List of spot-groups over 500 in area which are within 7° longitude of each other, and having − latitudes (from 1880 to 1884).

(These lists give group, number, date, longitude, latitude, and direction of motion.)

5. List of spot-groups over 500 in area in order of longitude and having + latitudes (years 1880 to 1884).
6. List of spot-groups over 500 in area in order of longitude and having − latitudes (years 1880 to 1884).
7. List of spot-groups over 500 in area within 5° longitude and two months' interval, giving the date, longitude, latitude, direction of motion, amount of motion in degrees, the number of days in which that motion takes place, and the velocity in miles per day.
8. List giving the mean heliographic latitude and mean distance from the equator of the spots upon the sun's disc for each rotation between April 27, 1874, and December 3, 1884. (This list was prepared at Greenwich.)
9. List of the velocities of currents carrying spot material, giving the number of the group and the velocity for those occurring in 1880.
10. Tables giving date, time, number of group.

Longitude, Latitude, Area, and Velocity for Year 1880.

The positions of the spot-groups over 500 in area for the years 1880–84 have been mapped on the globe at South Kensington. This enables the following data to be at once obtained:

1. The longitude and latitude (whether — or +) of the centre of gravity of the areas of the spots.
2. The size of the groups, that is, whether they are of areas between 500 and 1,000, or over 1,000.
3. The direction of motion of the spots.
4. Having got the longitude and latitude of a particular group; the date and number of groups may be obtained by referring to the list giving the spot-groups in order of longitude for the years 1880–84.

Solar Meridian.

The annexed table of Dates of Coincidences of the assumed prime meridian of the Sun with the central meridian of the visible hemisphere, prepared by the Astronomer Royal, has been forwarded to the various Solar observers with whom the Committee have been in communication.

DATES of COINCIDENCE of the Assumed Prime Meridian of the Sun with the Central Meridian of the visible Hemisphere.

Year	Date	d.	Greenwich Civil Time. h.	m.	Day of Year and decimal of Day. d.
1873	July	28	14	0,93	208·5840
	August	24	19	36,24	235·8168
	Sept.	21	1	54,13	263·0793
	October	18	8	46,20	290·3654
	November	14	16	2,07	317·6681
	December	11	23	38,27	344·9849
1874	January	8	7	35,72	7·3165
	February	4	15	47,32	34·6579
	March	3	23	50,02	61·9931
	March	31	7	11,77	89·2998
	April	27	13	31,53	116·5636
	May	24	18	52,58	143·7865
	June	20	23	40,51	170·9865
	July	18	4	29,74	198·1873
	August	14	9	48,87	225·4089
	Sept.	10	15	50,50	252·6601
	October	7	22	30,56	279·9379
	November	4	5	38,01	307·2347
	December	1	13	6,18	334·5460
	December	28	20	55,44	361·8178
1875	January	25	5	3,47	24·2107
	February	21	13	13,49	51·5510
	March	20	20	55,06	78·8716
	April	17	3	40,33	106·1530
	May	14	9	22,51	133·3906
	June	10	14	19,50	160·5969
	July	7	19	4,08	187·7945
	August	4	0	8,79	215·0061
	August	31	5	53,10	242·2452
1875	Sept.	27	12	19,06	269·5132
	October	24	19	16,83	296·8034
	November	21	2	37,08	324·1091
	December	18	10	18,05	351·4292
1876	January	14	18	19,92	13·7638
	February	11	2	32,43	41·1059
	March	9	10	29,10	68·4369
	April	5	17	38,68	95·7352
	May	2	23	44,63	122·9893
	May	30	4	55,80	150·2055
	June	26	9	41,02	177·4035
	July	23	14	34,53	204·6073
	August	19	20	2,08	231·8348
	Sept.	16	2	12,55	259·0920
	October	13	8	59,32	286·3745
	November	9	16	11,57	313·6747
	December	6	23	44,42	340·9892
1877	January	3	7	38,65	2·3185
	January	30	15	49,41	29·6593
	February	26	23	56,18	56·9074
	March	26	7	27,21	84·3106
	April	22	13	58,18	111·5821
	May	19	19	28,03	138·8111
	June	16	0	19,19	166·0133
	July	13	5	5,66	193·2123
	August	9	10	17,92	220·4291
	Sept.	5	16	11,72	247·6748
	October	2	22	45,60	274·9483
	October	30	5	48,80	302·2422

Date.			Greenwich Civil Time.		Day of Year and decimal of Day.	Date.			Greenwich Civil Time.		Day of Year and decimal of Day.
		d.	h.	m	d.			d.	h	m	d
1877	November	26	13	13,18	329·5510	1880	August	4	10	[illegible]	216·150[illegible]
	December	23	20	59,24	356·8745		August	31	16	31,60	243·6907
1878	January	20	5	4,99	19·2118		September	27	23	[illegible]	270·[illegible]
	February	16	13	16,82	46·5533		October	2[illegible]	6	0,92	298·250[illegible]
	March	15	21	5,69	73·8790		November	21	13	21,94	325·[illegible]
	April	12	4	1,94	101·1680		December	18	21	3,64	352·877[illegible]
	May	9	9	51,35	128·4127	1881	January	15	[illegible]	6,20	14·21[illegible]
	June	5	14	57,09	155·6230		February	11	13	18,[illegible]	41·[illegible]
	July	2	19	41,14	182·8205		March	10	21	13,8[illegible]	68·8816
	July	30	0	10,97	210·0284		April	7	4	20,50	96·1814
	August	26	6	17,22	237·2619		May	4	10	21,0[illegible]	123·[illegible]
	Sept.	22	12	37,13	264·5258		May	31	1[illegible]	33,[illegible]	150·[illegible]
	October	19	19	20,09	291·8125		June	[illegible]	20	18,[illegible]3	177·8[illegible]
	November	16	2	16,37	319·1155		July	2[illegible]	1	[illegible]	205·0[illegible]
	December	13	10	23,85	346·4329		August	21	6	12,08	23[illegible]·279[illegible]
1879	January	9	18	21,75	8·7651		September	17	1[illegible]	[illegible],29	2[illegible]·[illegible]84
	February	6	2	33,06	36·1069		October	14	19	13,[illegible]	286·[illegible]
	March	5	10	35,88	63·1116		November	11	[illegible]	[illegible],30	314·12[illegible]
	April	1	17	55,62	90·7470		December	8	10	29,73	341·[illegible]
	April	29	0	12,80	118·0089	1882	January	4	18	21,18	3·76[illegible]
	May	26	5	31,06	145·2305		February	1	2	[illegible]	31·107[illegible]
	June	22	10	19,30	172·4301		February	28	10	10,81	58·[illegible]
	July	19	15	9,30	199·6315		March	27	18	9,56	8[illegible]·[illegible]
	August	15	20	20,98	226·8542		April	24	0	37,8[illegible]	113·0[illegible]
	September	12	2	33,16	254·1064		May	21	6	5,61	140·[illegible]
	October	9	9	14,25	281·3849		June	17	10	[illegible],19	167·[illegible]
	November	5	16	22,25	308·6821		July	14	15	13,[illegible]	194·[illegible]
	December	2	23	51,10	335·9938		August	10	20	[illegible]	221·87[illegible]
	December	30	7	41,30	363·3203		September	7	[illegible]	55,[illegible]	[illegible]
1880	January	26	15	50,00	25·6598		October	4	9	[illegible],00	276·[illegible]
	February	22	23	50,83	52·9909		October	31	16	33,10	303·[illegible]
	March	21	7	39,61	80·3192		November	27	23	58,11	330·9959
	April	17	14	22,20	107·5988		December	2[illegible]	7	11,78	358·[illegible]
	May	14	20	1,85	134·8346	1883	January	21	1[illegible]	[illegible]1,00	20·[illegible]
	June	11	0	57,51	162·0399		February	18	0	2,37	48·0016
	July	8	5	42,30	189·2377		March	17	7	49,13	75·3200

Date.			Greenwich Civil Time.		Day of Year and decimal of Day.
		d.	h.	m.	d.
1883	April	13	14	12,24	102·6127
	May	10	20	32,80	129·8561
	June	7	1	34,09	157·0653
	July	4	6	18,55	184·2629
	July	31	11	19,37	211·1718
	August	27	16	58,20	238·7071
	September	23	23	19,07	265·9716
	October	21	6	13,08	293·2591
	November	17	13	30,32	320·5627
	December	14	21	8,23	347·8807
1884	January	11	5	7,53	10·2136
	February	7	13	19,87	37·5555
	March	5	21	20,51	64·8892
	April	2	4	37,57	92·1928
	April	29	10	51,74	119·1526
	May	26	16	8,72	146·6727
	June	22	20	55,40	173·8718
	July	20	1	46,25	201·0738
	August	16	7	8,80	228·2978
	September	12	13	13,95	255·5514
	October	9	19	56,68	282·8310
	November	6	3	5,85	310·1291
	December	3	10	35,69	337·4414
	December	30	18	26,83	364·7686
1885	January	27	2	36,07	26·1084
	February	23	10	44,98	53·4479
	March	22	18	22,35	80·7656
	April	19	1	1,74	108·0420
	May	16	6	38,64	135·2768
	June	12	11	32,98	162·4812
	July	9	16	18,21	189·6793
	August	5	21	26,08	216·8931
	September	2	3	14,51	244·1351
	September	29	9	43,97	271·4055
	October	26	16	43,99	298·6972
	November	23	0	5,95	326·0041
1885	December	20	7	48,64	353·3255
1886	January	16	15	51,92	15·6611
	February	13	0	4,09	43·0028
	March	12	7	57,67	70·3317
	April	8	15	1,80	97·6262
	May	5	21	2,19	124·8765
	June	2	2	9,84	152·0902
	June	29	6	51,61	179·2879
	July	26	11	50,60	206·4935
	August	22	17	22,25	233·7238
	September	18	23	36,47	260·9837
	October	16	6	25,83	288·2679
	November	12	13	39,66	315·5692
	December	9	21	13,91	342·8847
1887	January	6	5	9,53	5·2150
	February	2	13	20,70	32·5560
	March	1	21	25,44	59·8927
	March	29	4	52,00	87·2028
	April	25	11	17,18	114·4705
	May	22	16	42,97	141·6965
	June	18	21	32,54	168·8976
	July	16	2	20,35	196·0975
	August	12	7	36,13	223·3168
	September	8	13	33,79	250·5651
	October	5	20	10,71	277·8408
	November	2	3	15,95	305·1361
	November	29	10	42,37	332·4461
	December	26	18	29,86	359·7707
1888	January	23	2	36,96	22·1090
	February	19	10	48,03	49·4500
	March	17	18	33,21	76·7731
	April	14	1	23,80	104·0582
	May	11	7	10,37	131·2991
	June	7	12	10,34	158·5072
	July	4	16	54,63	185·7046
	July	31	21	56,58	212·9143

Date.			Greenwich Civil Time		Day of Year and decimal of Day.	Date.			Greenwich Civil Time		Day of Year and decimal of Day.
		d.	*h.*	*m.*	*d.*			*d.*	*h.*	*m.*	*d.*
1888	August	28	3	37,20	240 1508	1889	May	28	2	15,55	147·1150
	Sept.	24	9	59,81	267·4165		June	24	7	31,67	174·3137
	October	21	16	55,24	294·7050		July	21	12	23,47	201·5163
	November	18	0	13,72	322·0095		August	17	17	17,81	228·7415
	December	15	7	52,90	349·3284		Sept.	13	23	54,77	255 9964
1889	January	11	15	53,31	10·6620		October	11	6	38,80	283·2769
	February	8	0	5,86	38·0041		November	7	13	48,89	310·5756
	March	7	8	5,18	65·3369		December	4	21	19,69	337·8887
	April	3	15	19,55	92 6386	1890	January	1	5	11,91	0·2166
	April	30	21	30,72	119·8963						

The dates are given in Greenwich Civil Time, reckoning from midnight to midnight and counting from 0 to 24 hours. The day of the year and the decimals of a day are reckoned from Greenwich midnight, January 1d. 0h.

The assumed prime meridian is that which coincided with the Ascending Node of the Sun's Equator at Mean Noon on 1854, January 1.

The assumed period of rotation is 25·38 mean solar days.

W. H. M. CHRISTIE.

Royal Observatory, Greenwich,
May 29, 1886.

APPENDIX IV.

SCHEME FOR AN INTERNATIONAL COMMITTEE ON SOLAR STUDIES.

(1.) *Report by Mr. Lockyer to the Solar Physics Committee on a Visit to the Solar Observatories in Italy and France.*

Some time ago I received instructions to proceed on a mission to Paris and Nice, in order to confer with the various astronomers on the aid which they might be willing to give the Committee, both by special observations and by supplying the Committee with their results at an earlier date than they could otherwise be obtained.

In the interval which elapsed between my receiving the orders to proceed and my actual visit certain events took place which made it important that I should include Rome among the places visited. These were:—

First.—That in consequence of the delay in the construction of M. Trepied's instrument he would not be able, in spite of his expressed willingness, to commence observations in less than a year.

Second.—That Professor Tacchini, although he was willing to commence new series of observations both at Rome and Palermo at once, was unable to meet me at Nice at that particular time.

I, therefore, began work at Rome, arriving there on the 6th March. Here I spent some days discussing with Professors Tacchini and Respighi the various methods in which co-operation might be advantageously employed, and especially the kind of observations which we might fully expect to get in the greatest abundance, in Italy. Professor Tacchini, who had studied the Committee's report, expressed his agreement with the principles laid down in it, and we drew up together the document which I here give which shows the assistance which the Italian observers, both at Rome and Palermo, are willing to render the Committee. I may state that the work relating to the length of the lines in prominences is new, and it will go on side by side with the old series of observations. The importance of the assistance thus offered to the Committee will be obvious when I state that in the months of January and February only one day's observations were missed, while here we could only secure observations on seven days. We discussed the question of publication. It was suggested, during the conversation, that it would be well to have for each day a combined picture giving spots and pro-

minences, and even perhaps other phenomena, such as the welling up of magnesium on the limb, on exterior concentric circles. Professor Tacchini expressed himself willing both for the past and the future to indicate round a paper positive of the sun's disc, for each day, the positions, height, and forms of the prominences and such other information as might be determined on. I have already forwarded to him paper positives so that, at a subsequent meeting of the Committee, this idea may be further discussed.

Professor Respighi expressed himself equally willing to aid the Committee, and we shall have no difficulty in obtaining from him observations, should he happen to possess them, on days when there are gaps in the other series.

Professor Tacchini, who had not long returned from observing the eclipse in the Caroline Islands, expressed his approval of that part of the Committee's report which suggested concerted action, by civilised Governments, in the matter of Eclipse Observations (Report, page 63). He supplied me with a memorandum, which I also append, urging that it is not, even now, too early to take steps for concerted action in 1886.

The Italian Government Solar Observatories from which we may expect observations are:—

1. Osservatorio Collegio Romano, Professor Tacchini.
2. Osservatorio Campidoglio, Professor Respighi.
3. Observatory of Palermo, Professor Ricco.
4. Observatory of the Casa Inglese on Etna.
5. A corresponding observatory at Catania for simultaneous observations at high and low levels.

From Rome I went to Nice, where I arrived on the 11th of March. The observatory at Nice, which has been endowed by the liberality of M. Bischoffheim, is situated on a hill some miles from the town at an elevation of 1,000 feet. Those parts of it which will be utilised for solar observations are as follows:—

1. A siderostat, with a 9-in. object glass of medium focus, and a Thollon spectroscope of great dispersion. Connected with this building is a physical laboratory in course of erection, which will be furnished with De Meritens and Siemens' dynamo-electric machines, and other adjuncts for obtaining metallic spectra side by side with that of the sun.

2. A magnificently mounted 15-in. refractor already in working order.

3. A 28-in. refractor in course of construction.

The scheme which had been foreshadowed by Professor Tacchini was discussed and agreed to, so far as M. Thollon was concerned, with the proviso, that it could not be commenced until a research on the Telluric lines, on which M. Thollon is now engaged, was completed.

While I was at Nice M. Thollon was engaged, among other matters, on a series of observations begun last autumn at the observatory of the Pic du Midi, which is being erected by the French Government for the use of the astronomers of France and other countries in the summer months. On the summit, at the height of about 10,000 feet, he found that at the moment of sunrise, and for one and a half hour afterwards, the definition of the sun was so perfect that the hydrogen surrounding each of the domes which Dr. Janssen has succeeded in photographing could be easily observed on the C. line; so that on moving the slit of the spectroscope along the sun, the C. line was no longer continuous, but was really built up of a series of sections of a mottled surface. This I observed many years ago during London fogs, but such observations have not been recorded elsewhere, so far as I can remember, until MM. Thollon and Trepied observed them on the Pic du Midi. M. Thollon finds at Nice that the time during which these delicate phenomena remain visible after sunrise is restricted with reference to the Pic du Midi. Indeed, at least sometimes half an hour after sunrise they had almost vanished in consequence of the disturbed state of the air. The moral of these observations, as it appears to me, is that we want a horizontal photoheliograph somewhere, the higher the better, to take a photograph of the sun on a large scale as soon as possible after sunrise each clear morning, and that the more delicate spectroscopic observations should be attempted at the same time.

M. Perrotin, the director of the observatory at Nice, discussed with me as to the best means of carrying on the stellar researches which they propose to inaugurate. M. Thollon had proposed a plan of facilitating the observations by means of mirrors. It is not necessary to give the exact details. I pointed out, however, that what we really wanted was, above all things, light, and that the time had now arrived when eye observations should give way to photographic ones, and that if this principle were accepted the half million francs or more which would be required for the observatory would be saved. The conversation ended by my suggesting an 8-feet mirror of from 40 to 60 feet focal length, with a skeleton tube, merely adapted for carrying a spectroscope and camera, the exposures in either case being

made by magneto-electricity. From subsequent inquiries made at Paris I find that such an instrument can be at once constructed, and that its cost will be less than one-third of the building which is to shelter the 28-in. telescope.

While at Nice I discussed with M. Thollon the observations of sun-spots which have been made here for the last five years. I left with him a complete set of maps of the first 200 observations, and he is engaged in studying the nature of the various lines reversed, with the enormous dispersion at his disposal. This is an important control for which, personally, I am very grateful to him.

From Nice I went to Paris, where I arrived on the 20th of March. My first duty here was to look after the photoheliograph, the construction of which was undertaken two years ago by M. Prazmowski.

I found that M. Janssen, who had previously reported to me that it was nearly finished, had been entirely misinformed. Owing to the serious illness of M. Prazmowski since last August, and the indescribable confusion which had arisen therefrom, several days were lost in trying to get at the facts. At last an object glass was handed to me, without a cell, which it was stated was the one ordered by the Committee. I was also informed that the secondary magnifier had not been commenced and, during M. Prazmowski's absence—and he is not very likely to return I hear—one could not be commenced.

I at once, therefore, went to the Observatory and begged of Brothers Henry to aid me:—First, by testing the object glass and then by making a secondary magnifier should it turn out to be the right one. The Brothers Henry at once acceded to my request, and we spent part of the next day at Mont Rouge in testing the object glass. We found that it had not been corrected for the photographic rays at all. I then made an additional appeal to make us an object glass corrected to G, as well as a secondary magnifier. This they most generously offered to do by the 1st of June, putting aside more lucrative work to enable them to accomplish it. This step having been approved by Colonel Donnelly, I then spent a day with M. Gautier in designing the body of the photoheliograph itself. The complete drawing, together with the estimate for 80*l.*, accompanies this report. This includes a trappe of Dr. Janssen's most recent form, which is of a very elaborate construction, and adapted for taking pictures at two seconds' interval.

While these negotiations were going on, and after they were terminated, I spent as much time as I could at

Dr. Janssen's observatory at Meudon, where every process was thrown open to me, and where, indeed, I took some photographs, following down to its most minute detail the manipulation which Dr. Janssen has found to be most satisfactory. My stay at Meudon was in all respects very agreeable and instructive to me, and I must confess that it gave me great satisfaction to find, from time to time, that the Meudon plates gave no more signs of mottling than many plates taken at Kensington. I think this seems to indicate that it is more the variable condition of the atmosphere than a constant climatic difference which is in question.

The greatest difference between Dr. Janssen's processes and our own are in the baths employed, their constant renovation, and the manipulation of the plate in the bath.

At present the pictures of 30 centimetres diameter are taken with an altazimuth with no wires; the orientation being determined by an exact record of the time at which each photograph is taken and the careful determination in the variation from true level at the upper edge of the plate.

At least three photographs are taken every day, one of which Dr. Janssen has expressed his willingness to place at the disposal of the Committee to fill up gaps when necessary.

The strength of Dr. Janssen's observatory has recently been increased by the accession of M. Trouvelot, whose astronomical drawings are so well known. Part of his daily routine duties is to make daily spectroscopic observations of the chromosphere, and it may reasonably be expected that these observations will supply gaps in the Italian series.

Dr. Janssen not only expressed his willingness to aid the Committee, but suggested that the matter of publication which was dealt with in Professor Tacchini's memorandum would be much aided, and economy of work and effort greater even than that brought about by our own Committee would be insured by the creation of an international one, each observatory, not only supplying its observations for a complete publication, but funds for the publication itself. I need not enlarge any further on this point, as when I was leaving Meudon Dr. Janssen expressed his intention to write a letter to the Committee embodying his ideas at length.

I cannot complete this report without stating to the Committee the great sympathy with their work which I found everywhere, and the firm belief warmly expressed by those whom I came across of the great value and economy of the co-ordinated system of work which they have proposed.

I may add in conclusion that since I left Paris, Captain Abney has taken advantage of a visit there to inquire into the progress of the photoheliograph and he found that both the optical and the mechanical parts were advancing at the rate which had been promised.

We may expect therefore that Dr. Janssen will be able to carry out his promised testing of the instrument early in June. If the Committee consider it desirable that I should be at Meudon at that time I should be glad to go there.

J. NORMAN LOCKYER.

(2.) *Memorandum by M. Tacchini.*

A Palerme comme à Rome on continuera à observer les spectres des protubérances métalliques, ainsi que les spectres métalliques dans les parties où il n'y a pas de protubérances. Chaque fois on enverra à M. Lockyer la description du phénomène, tenant compte le mieux possible de la longueur des lignes observées avec la fente tangente, comme on en use en Italie: et, s'il est possible, accompagner la description de dessins pour les différentes couleurs comme l'a fait autrefois Tacchini.

Il ne sera pas bon de diviser le travail pour les différentes parties du spectre, car les éruptions métalliques étant des phénomènes d'une durée ordinairement courte, on aurait souvent une observation incomplète. A Rome donc, comme à Palerme, on devra parcourir le spectre entier.

Il serait désirable que le même travail qu'on fait à Rome et à Palerme avec des moyens parfaitement égaux, soit fait aussi avec des appareils plus puissants, comme ceux dont disposent MM. Thollon et Trépied. Dans ce cas on pourra diviser le travail, c'est-à-dire faire l'observation de la moitié du spectre à Nice, et de l'autre moitié à Alger.

Il serait désirable qu'outre les observations des spectres métalliques, que presque toujours on observe en bas, des observations soient faites même dans les protubérances ordinaires de quelque importance, c'est-à-dire assez hautes pour voir si l'on peut observer avec un spectroscope puissant des lignes métalliques.

Il faut étudier la manière la plus convenable de publier les observations solaires directes et spectroscopiques, de manière à rendre facile la comparaison et l'étude des différents phénomènes.

PIETRO TACCHINI.

Rome, 10 Mars 1884.

(3.) *M. Janssen's Scheme.*

(*Translation.*)

SIR,

The English Committee on Solar Physics has honoured me by asking my opinion on the methods likely to promote the progress of the solar studies with which your Committee deals.

I would have answered your invitation sooner had it not been for my desire to examine more thoroughly a subject of study which is common to us. But Mr. Lockyer's visit to Paris, and the special invitation which that *savant* addressed to me on your behalf, have determined me to send to you at once the result of my reflections on this matter.

After much reflection on the methods now employed in studying the surface and the edges of the sun, either by means of the eye, of photography, or of the spectroscope, I am more than ever convinced that these labours, which derive their value from the uniform and continuous nature of the observations, can no longer comply with the demands of science without the establishment of a concert or union between the observers.

With the admirable means of study available in photography and the spectroscope, we can only succeed in producing isolated series, disconnected, and with gaps which deprive them of nearly all their value.

What is true for the labours themselves is still more so for their publication. Every one publishes according to his means and his ideas of the object to be attained. Hence publications dissimilar both in size and method.

It therefore seems to me that the time has decidedly come when observers, who deal with regular observations of the sun, should combine their efforts and regulate their labours. This object would be attained by forming a Committee, to be termed "the International Committee on Solar Studies." Its mission would be to examine the best methods of observation, to promote their application, to establish a uniform plan of observations, and finally to collect them.

Observations.—The Committee, after investigating the existing elements of study due to participating institutions and observers, could make out a scheme of observations in which each one would have the part accepted by him, and suitable to his tastes, his acquirements, and his means.

This plan would comprise ocular, spectroscopic, and photographic observations. The Committee would en-

deavour to fill up as soon as possible the gaps which must inevitably occur at first, and with this view would either seek to obtain more adhesions, or to promote the creation of fresh centres of observation.

Publications.—But it is especially in the way of publication that the Committee would be of signal service to Science. It could concentrate, calculate, arrange, and publish labours in such a manner as to establish, for each kind of observations, series as complete and lengthy as possible, utilising for the purpose all the observations of its members, and also, if neccssary, those of outsiders, with their previous consent. The Committee might even undertake to go backwards, and to re-constitute, with such data as might be found, a series invaluable for a retrospective history of the sun.

All the observations thus collected, calculated, and carefully published would form collections of inestimable value, both for present workers, and for those of posterity.

What should we not know now did we only possess such data relating to the past of the sun?

As to the cost of such calculations, of reduction, and of publications, it might be met by contributions from each of the members of the Committee. Individually this would certainly be less heavy than the expense of a separate publication, and each member would thus enjoy the immense advantage of receiving the complete work of all his fellow-workers. But there can be no doubt that in a near future such a Committee, representing, as it would, the most eminent authority in this branch of study, would receive from Governments and societies supplementary funds that would enable it to considerably extend its action.

Such is the proposal which I have the honour to submit to the *savants* who deal with solar studies.

Should this proposal be accepted, it would be well, in the first place, to form the nucleus for the final Committee. This nucleus, consisting of the highest authorities on the subject who, would be the *founders* of the undertaking, would examine the primary questions of organisation and framing of rules; after which it would apply to all those who might usefully co-operate in various capacities, and the final Committee would then be formed.

In order that the Committee should really be of an international character—the only one that can secure for it numerous adhesions and enable it to attain its object—it would be advisable:—

That the President should be elected at each Congress.

That the Congresses should be held alternately in the principal scientific centres where there are co-operators.

That the publications of the Society should appear in several languages, such as English, French, German, Italian. As the publication of these labours will chiefly consist of drawings and figures, this would be very easy.

(Signed) J. JANSSEN.

Observatory of Meudon,
16th May 1884.

APPENDIX V.

Letters on the Subject of a Conference on Solar Physics.

(Translation.)

Registered No. 29,573, 1885.

Potsdam, May 28, 1885.

SIR,

An Astronomical Congress will be held at Geneva from the 19th to the 22nd August, which I propose to attend, and have already written to that effect to Professor Schönfeld of Bonn. I shall there explain my researches of the last few years. The printing of these researches will soon begin. At the end of the Geneva Conference I thought of remaining a few days longer in Switzerland, and it might be that I could come at the end of August to take part in the London Conference.

I could only come to London, however, on the understanding that my travelling and personal expenses are paid. I cannot expect our Ministry to pay these costs, and do not know if they will be met on your part. If I get from you an assurance that they will be paid by you I would readily participate in the Conference; while this is doubtful I will express my views, in accordance with your wish.

The project of M. Janssen to the extent indicated, I hold to be unacceptable. The independence of the worker would be too much circumscribed, and this is injurious to free research. Besides, those who like myself have been working independently for some years would not be inclined to make themselves dependent on the Committee.

Only in one respect can I regard the institution of a Committee as desirable, viz., for the publication of charts similar to that of which I enclose a proof. The scale might be somewhat larger. Respighi has issued such charts, also P. Secchi for some years. I should like, however, charts like this one according to the heliographic breadth of the protuberances. When once it is determined what scale is to be used, each observer could prepare himself a drawing according to it, which could easily be lithographed in the row to which it belongs. The name of the observer should be added. It would not be without advantage if several observations are subjoined for the same day in order to determine the variations and to fix periods; this being specially desirable when a spot is found on the extreme edge. I, myself have many observations which have not yet been published, and which I might send. One must begin with

the year 1870. I will not enter specially into the advantages of such charts but mention one only. It is very important when the protuberances in the region are further north or south if there is simultaneously a spot on the extreme outer edge. I have given many cases in which the protuberances had a contrary direction or appeared in the region as divergent clusters. This had not been noticed.

The compilation of the materials of observations in the manner indicated I would entrust to the Committee, but nothing further. Their use and manipulation must be left to individuals, on their own responsibility, and not be invested with the authority of the Committee.

The compilation of the sun-spot regions (directly observed with a telescope or taken by photography) I would *not* entrust to the Committee nor yet the computation of the regions. As to the "rotation elements" no agreement need be expected in the near future; their computation, also, must be left to individual observers. For observation no definite *principia* are followed. Faye laid down in the Compte Rendu that the measurement should be from the Dawes dark point in the nucleus, but Faye himself is not an observer, and consequently cannot know that his proposal is not practicable. If a large spot has several *nuclei* one observer measures the centre of the whole spot while another seeks out the largest nucleus, and finds nothing to refer the variations. Such published observations as these I cannot use for my researches. One must have regard for the variations, especially if one wishes to contemplate a particular spot as identical with a spot of the following rotation period. The centre of a largely affected appearance in the first rotation period is *not* identical with the centre of a smaller spot of the second period, and if one considers them as identical there will at once be a too deep parallax. My observations which I am about to publish contain a confirmation of my former deep parallax (including refraction), viz., the sectional. Accordingly a correction belongs to the calculated regions, and is necessary.

For the prosecution of researches for the exact determination of Ω and i, I would observe that it cannot be expected that out of the discussion of a very large number of spots the right elements can be found, but one has to pick out those which are preferable. A good result would follow if it were assumed that the difference in the variation of longitude arises, if one takes a nearly similar number of spots in both hemispheres. My researches (which are not published) show that the northern hemisphere in respect to

the variation of the heliographic longitude is different from the southern hemisphere, and the difference is more specially marked between 0° and 10°.

In the Conference it would be well to arrive at an understanding that everyone should so publish his observations that they could be used with facility. The distance and positions angle must be given. In the Greenwich observations there are given the distance from centre and position angle from sun's axis. The last-named I cannot use, and must go backwards to find the positions angle for the direction of the earth's axis in order to find the point from which to reckon my constants.

I should like, too, if an understanding could be come to, to reckon solar observations in the civil fashion, so that, for instance, the *beginning* of June 2nd should be *not* at midday but the preceding midnight, and that midday of the 2nd June should be denoted by 2,500.

A discussion of the rules for surface measurement (area) is much to be wished for, for it is only probable that one has in area a reliable measure. I have therefore determined frequency after another principle.

Respectfully yours,

(Prof.) Dr. Spoerer.

(Translation.)

Registered No. 29,523, 1885.

Zurich, 30th May, 1885.

Sir,

I don't think my age and occupations will allow of my being present at the proposed Conference, but I need not tell you that I take a warm interest in the project for the centralisation in a manner to be agreed upon, of the efforts of the various *savants* who occupy their time in the study of our sun.

Such a centralisation is absolutely necessary for the figures taken by the aid of *photography* and *spectroscopy* and perhaps also for *micrometric* determinations of the positions of sun-spots—since relative observations have been up to the present time made without the necessary uniformity. It would unquestionably be of the greatest importance if it were possible to unify the results obtained, to equalise them, and publish them in a uniform manner. In this respect I adhere to the views and proposals of M. Janssen which you have communicated to me.

For *eye observations,* and specially for the enumeration of sun-spots, I think I have already done what should be done for photographic, spectroscopic, and micrometric observations, for there will be found united in my periodical "Astronomische Mittheilungen" both all the materials which have come down from past ages and the results of the regular enumerations obtained by various observers in own time—not only individual observations, but also the *homogeneous series* that it has been possible for me to compile with an enormous amount of toil. I do not believe it will be possible to do anything much better, and I am ready to go on with this arrangement and with this publication to the end of my days. If there exists series, which it has been impossible for me to classify with others up to the present time, because I have not known them or had them, I am still ready to calculate and publish them as soon as they are sent to me.

Yours very sincerely,

(Signed) R. WOLF.

(*Translation.*)

Registered No. 29,953, 1885.

M. LE PRESIDENT, Rome, June 4, 1885.

I am in receipt of your kind invitation to the meeting of the Solar Physics Committee, and desiring to take part in it, I have asked my Government for permission to do so. But as I must be present at the meeting of the International Committee on Meteorology meeting on the 1st September at Paris, I could only stay in London a very few days, viz., from the 25th to the 30th August. In the event of the meeting being held before this, I will communicate my views by letter to the Committee. I ought, however, at once to state that I am not inclined to such a society as my illustrious friend M. Janssen proposes, for I do not think the undertaking practicable. Those who occupy themselves with Solar Physics are very few in number and we hardly know each other. At present it would suffice to entrust the English Committee with the task of improving the study, as it tends to do, and of publishing ancient and modern observations with the funds of the Committee assisted by the different Governments. These funds should not be employed for meetings in the principal scientific centres.

The Committee should I think at present be permanent, and if necessary to call meetings, there is nothing to do but summon afresh to London those who really pursue the study of Solar Physics.

Yours very faithfully,
(Signed) P. TACCHINI.

(*Translation.*)

Registered No. 30,077, 1885.

Astro-Physical Observatory, Potsdam,
June 5, 1885.

In reply to your honoured letter of the 19th May, I beg to state that I am not at present in a position to state positively whether I shall *personally* be able to attend the proposed Conference in London between the Solar Physics Committee and various foreign scientific celebrities. The time selected, viz., end of August would at one time have suited me well enough. If I cannot come myself, perhaps I can send in my stead Professor Spörer or Dr. Lohse, who hold appointments in the Astro-Physical Observatory at Potsdam under my direction.

Generally, I may remark that I am in sympathy with the objects of the Committee in harmonizing the action of solar observers throughout the globe with reference to the arrangement and publication of their observations, and that I will readily support their endeavours with the rich store of instruments at the disposal of the observatory.

Respectfully yours,
(Prof.) Dr. H. C. VOGEL,
Director of the Astro-Physical Observatory.

The Secretary,
Solar Physics Committee.

Registered No. 30,075, 1885, from A. Schuster, Esq., Ph.D., F.R.S. Letter dated 6th June 1885. "Hopes he "will be able to attend the last 10 days of August."

Registered No. 30,205, 1885, from Professor Riccò, of Reale Observatorio, Di. Palermo. Letter dated 8th June 1885. "Expresses his desire to attend, and has addressed "an application on the subject to the Italian Government."

Registered No. 31,561, 1885.

Princeton, New Jersey, U.S.A.,
10th June 1885.

SIR,

I have duly received yours of May 19th, and sincerely regret that it will not be in my power to attend the proposed meeting of men of science engaged in solar research. I heartily approve the plan, and am greatly honoured by the invitation to be present, but family considerations make it impossible for me to go abroad this summer.

As regards the scheme of Dr. Janssen, while I have not time as yet to examine and form an opinion upon every point involved, I think it on the whole a very admirable one; one which would secure a rapid increase of our knowledge.

I should be happy to co-operate with the proposed "*Comité international des études solaires*" to the extent of my ability.

The only difficulty I feel relates to the pecuniary resources. I could not promise any considerable contribution from my *private* means, and at present I have no other funds in my control. Were such a Committee formed, however, I should have some hopes of being able to obtain a grant from the University to supply my quota; but I am not in a position to make absolute promises.

I am, Sir,
Very respectfully,
Your obedient servant,
(Signed) C. A. YOUNG,
Professor of Astronomy.

Frank R. Fowke, Esq.,
Secretary to Solar Physics Committee.

Registered No. 31,699, 1885.

Harvard College Observatory,
Cambridge, U.S.,
11th June 1885.

SIR,

Your letter of May 19th has been duly received. Other occupations will deprive me of the pleasure of attend-

ing the meeting to be held for the introduction of improved methods in solar research. I entirely approve of co-operation in such matters, but it is probable, as was explained in my letters of February 25th and November 3rd, 1884, that the chief part in the proposed work which can be taken by this observatory, at least unless its funds should be increased, will consist in furnishing for measurement such photographs from the series formerly taken here as may be thought most useful in filling gaps in other records made between 1870 and 1876 inclusive.

With regard to the plan of co-operation proposed by M. Janssen, it only occurs to me to suggest that the Committee superintending the work might advantageously be connected with the International Association, the formation of which has been proposed at recent meetings of the British and American Associations for the advancement of Science.

Yours respectfully,

(Signed) EDMUND C. PICKERING.

Frank Rede Fowke, Esq.,
Secretary to the Solar
Physics Committee.

APPENDIX VI.

Circular Letter to Directors of Solar Observatories on International Co-operation.

SIR,

I have already had the honour of communicating with you on the subject of international co-operation in the making and publication of Solar Observations.

In my last letter I stated that it had been necessary to abandon the proposed conference on account of the difficulty of fixing a time which would be generally convenient. The object which the Solar Physics Committee has in view, at the present time, is to endeavour to see therefore whether the desired co-operation can be brought about by means of correspondence.

The labours of the Committee both before and since the date of my last letter have resulted in arrangements which may be expected to secure a solar photograph on a scale of at least 8 inches to the sun's diameter for every day in the year. These photographs are taken at Greenwich, in India, Mauritius, and Australia.

Arrangements have also been made by which the reductions of these photographs are undertaken by the Astronomer Royal; these reductions include heliographic latitudes, longitudes, and areas of spots, and also positions and areas of faculæ, the areas being stated in millionths of the sun's visible hemisphere.

For these reductions, the solar rotation of 25·38 mean solar days is taken, and the assumed prime meridian is that adopted by Carrington, so that the reductions made at the present time are based on the same data as those assumed in Carrington's series.

The Solar Physics Committee are willing to take such steps as will enable them to place these reductions in the hands of all solar observers at the earliest possible moment; and if adequate co-operation can be secured, they believe they will also be able to supply copies of the daily photographs.

The Committee believe that if this information could be placed in the hands of observers at an early period after the day of observation, much time now spent in determining positions of spots whether from drawings or photographs might be saved for other inquiries.

The Committee could at the same time distribute, for general information, the observations of the most widened lines in sun-spot spectra, which are secured on every possible occasion at Kensington.

These two branches of the work, however, by no means meet our scientific needs.

The positions, heights, and chemical constitution of all prominences, whether metallic or not, and of all wellings up in the chromosphere, are perhaps as important as the positions, areas, and chemical constitution of the spots.

The observations of both series of phenomena will acquire a ten-fold importance the moment they are strictly co-ordinated, and reduced on a uniform plan, and the Committee believe that daily registry of the Solar Phenomena cannot be considered complete until all observations have been discussed.

Assuming that this view may commend itself to those who now carry on solar observations, the Committee have contemplated the possibility of this latter class of observations being sent to them, so that they may be published with the data which they already possess relating to the spots for the same period.

If this were carried out there would be an international bulletin giving the reduction on a uniform plan of all the observations regularly made every day, of all solar phenomena which it may be determined to photograph or observe.

Such a regular chronicling for general use of ordinary phenomena would of course in no way interfere with any special researches which might be undertaken in connexion with any one of them.

Accompanying this letter is a suggested form of bulletin, indicating, in a rough and preliminary manner, the kind of way in which such information may be brought together. The Committee will be obliged if you will favour them with your criticisms or suggestions.

They would also inquire if you would be prepared to associate yourselves with them in carrying out such a scheme; and if so, what class of observations you would be prepared to make and forward regularly to the Committee.

To facilitate any work which you may be prepared to undertake in this subject I enclose a table drawn up by the Astronomer Royal giving the dates of coincidence of Carrington's assumed prime meridian of the sun with the central meridian of the visible hemisphere up to the end of the year 1889.

Finally, as there would necessarily be expenses attendant

on the issue of such a bulletin, I am directed to observe that if there is any fund at your disposal from which a proportional part of such expense might be contributed, or if you were able to subscribe for a certain number of copies of the bulletin, at a price to be fixed hereafter, it would assist materially in giving practical effect to the proposed scheme.

APPENDIX VII.

REPORT by Professor Lockyer on the Relation of the Sun to other Celestial Bodies, being conclusions based on the results of work done at South Kensington.

(1.) *Laboratory Work.*

The laboratory work has consisted of—

(1.) Experiments upon the spectrum of carbon.

(2.) Experiments upon the luminous phenomena of the various metals volatilised in the Bunsen burner and in the oxy-coal-gas flame, as compared with the phenomena seen at higher temperatures.

(3.) Experiments upon the spectrum of magnesium at low temperatures.

(4.) Experiments upon the glow of sodium and magnesium in vacuum tubes.

(5.) Experiments upon conditions under which the C and F lines of hydrogen disappear from the spectrum.

(6.) Observations of the spectra of meteorites in the oxy-coal-gas flame.

(7.) Observations of the spectra of meteorites when made to glow in vacuum tubes.

(8.) Observations of the spectra of meteorites at the temperature of the quantity spark without jar.

(9.) Photographic comparisons of the solar spectrum with the spectra of meteorites in the electric arc.

(2.) *Observatory Work.*

The 10-inch equatorial has been employed in conjunction with a small star spectroscope for the observations of the spectra of stars and nebulæ. Attention has been chiefly directed to the differentiation of stars, like the sun, which are cooling from stars at a nearly equal temperature which are getting hotter. For this particular inquiry the observations which have been published by other observers are not sufficiently detailed to enable the necessary criteria to be determined. Hitherto only one line of temperature, and that a descending one, has been considered by observers.

Detailed examinations have been made of nearly 30 stars, the lines being directly compared with lines in the electric spark and Bunsen burner in each case.

(3.) *General Conclusions.*

The conclusions with regard to the sun are embodied in a general scheme which embraces all the celestial bodies with which we are acquainted.

The main conclusions are :—

(1.) All self-luminous bodies in space are composed of swarms of meteorites or masses of meteoritic vapour produced by the heat brought about by condensations of meteor swarms due to gravity.

(2.) The spectra of all such bodies depend upon the heat of the meteorites, produced by collisions, and the average space between the meteorites composing the swarm; or, in the case of consolidating vaporous masses, upon the time which has elapsed since complete vaporisation.

(3.) The temperature of the vapours produced by collisions in nebulæ in the so-called "stars" with bright line spectra without the C and F lines of hydrogen, and in comets away from perihelion, is about that of the Bunsen burner. The principal lines seen in these bodies can be reproduced in the laboratory experiments.

(4.) The temperature of Orionis and similar condensing swarms is about that of the oxy-coal-gas flame.

(5.) The next stage in the condensation of a swarm before complete vaporisation is represented by such stars as α Tauri, the temperature of which does not differ greatly from that of the sun.

(6.) Complete vaporisation of the swarms is represented by stars like Vega and Sirius, in which little but hydrogen absorption is seen.

(7.) The first marked stage in the subsequent cooling is represented by stars like the Sun, Capella, and Arcturus.

(8.) The last stage of cooling prior to entire loss of inherent luminosity is represented by stars of the same type as 152 Schjellup, where there is mainly the absorption of carbon vapour.

(4.) *New Classification of Celestial Bodies.*

Although nebulæ and comets have hitherto been regarded as things quite distinct from stars, this distinction is no longer necessary. All previous classifications of the celestial bodies

have been based on the assumption that this difference existed, and that all the stars were cooling, but it is obvious that they must give way if there be a line of increasing as well as a line of decreasing temperatures; that is, if some stars are getting hotter whilst others are getting cooler. It has now been demonstrated that the old Class III*a*. stars are meteor-swarms which will ultimately develop into stars of the α Lyræ type, and that the Class III*b*. stars have passed through all the other stages. It is clear, therefore, that these two classes cannot possibly be successive stages of development of the same type, nor is it possible to conceive that they are different types of the development of any one stage, as Vogel's and Leuchi's classifications suppose.

The general classification suggested by the work at Kensington is as follows:—

Group I.—Radiation lines and flutings predominant, absorption begins in the last species. Nebulæ, comets near aphelion, and the so-called stars with bright-line spectra are included in this group.

Group II.—Mixed carbon fluting radiation and metallic fluting absorption predominant. This group corresponds to the old Class III*a*., and also includes some comets near perihelion.

Group III.—Line absorption predominant with increasing temperature. The more advanced members of the group will have the simplest spectra. One division of the old Class II*a*., stars fall in this group.

Group IV.—Simplest line absorption (hydrogen) predominant. This group corresponds to the old Class I. and includes only the very hottest stars, like Sirius and Lyræ.

Group V.—Line absorption predominant with decreasing temperature. Those stars of Class II*a*. which do not fall in Group III. will fall in this group.

Group VI.—Carbon absorption predominant. This group corresponds to the old Class III*b*.

Group VII.—Dark planetary bodies. In this new classification there are several fundamental departures from previous ones. As far as solar physics is concerned, however, perhaps the most important is the division of the old Class II*a*. into two groups, one representing increasing and the other decreasing temperatures. On the ascending side of the temperature curve the varying volatilities of meteoritic constituents brought out by successively higher

temperatures are in question, whilst on the descending side of the curve the spectra will depend upon successive chemical combinations rendered possible by a gradual reduction of temperature in a gaseous mass.

The spectroscopic observations of the II*a*. stars have hitherto been made on the supposition that all of them were cooling bodies, so that no effort has been made to establish the necessary criteria. The spectroscopic criteria which will enable observers to assign any particular Class II*a*. stars to either Group III. or Group V., as the case may be, of the new classification have recently been determined by work in the observatory.

(5.) *Tests.*

As a test of the truth of the hypothesis, Mr. Lockyer shows how it bears the strain put upon it when it is used to indicate how the groups should be still further divided, and what specific differences may be expected. Thus, the first species of Group I. will include the least condensed swarms, and succeeding species will include the more condensed ones. The last species of all will consist of the hottest of the "stars" with bright lines, like γ. Cassiopeiæ. In passing through this series, the spectroscopic differences observed between the different species are just what would be expected on the supposition that meteorites at gradually increasing temperatures are in question, and the general hypothesis is thus greatly strengthened.

It is also shown that if the next group (Group II.) be discussed in a similar manner, the same conclusion is arrived at. The actual spectroscopic differences observed are exactly what they would be in a condensing swarm of meteorites with a gradually increasing temperature. The 297 stars of this group which have been observed by Duner have been divided by Mr. Lockyer into 15 well defined species, the first beginning where the last of the preceding groups leave off.

The subject of variability, as far as it is associated with the stars which Mr. Lockyer has shown to be uncondensed meteor-swarms, was also considered at some length in the Bakerian Lecture. Mr. Lockyer's explanation of variability is closely allied to that of Newton, who ascribed the increase of brightness to the appulse of comets.

According to Mr. Lockyer, however, the variability in this class is produced in the simplest case by the revolution of a

small meteor-swarm round a central one, the maximum occurring at periastrion. The greater the eccentricity of the orbit of the revolving swarm the greater will be the difference between the luminosity at maximum and that at minimum. Variables of this group are therefore to be regarded as incipient double stars, the invisibility of the companion being due to its nearness and the primary, or to its faintness. The question of variability affords several tests of the general hypothesis. According to the hypothesis, stars of Group II. ought to be more subject to variability than the other groups, and, as is well known, this is the case. Variability ought also to be most common in the swarms with a mean condensation, for the reason that at first the meteorites are too sparse for many collisions to occur, and that finally the outliers of the central swarm are drawn within the orbit of the revolving swarm, so that there are very few additional collisions at periastrion. A discussion of the recorded observations has shown that this is the case, the greatest number of variables occurring in those swarms where spectroscopic observations indicate mean spacing. In cases where there is more than one maximum, it is suggested that more than one revolving companion is concerned. This general view of variability, however, does not exclude other causes, such as eclipses by dark companions.

In a later paper read at the Royal Society on January 10, 1889, Mr. Lockyer discussed the spectra of comets and the aurora, and the origin of binary stars, with the special object of testing the general hypothesis. The first part of the paper dealt with the spectra of comets. It being generally accepted that comets are meteor-swarms in the solar system which get brighter, and therefore hotter, as they approach the sun, if the hypothesis be true, the changes in their spectra ought to resemble those which take place in gradually condensing swarms outside the solar system. A detailed discussion of all the available spectroscopic observations of comets shows that this demand is satisfied by the facts. An important outcome of Mr. Lockyer's investigations of cometary spectra is in the unravelling of the spectroscopic phenomena produced by the integration of various simple spectra. The cause of the variation in the form of the citron band in cometary spectra, for example, has always been a difficult question, but Mr. Lockyer shows that such variations as are observed are not only explained but demanded by his hypothesis. Allowing for the differences in the conditions of observations, it is conclusively shown that the sequence of spectra is the same in comets as in

condensing nebulæ. In both cases when the number of collisions is just sufficient to render the swarms visible, *i.e.*, in comets at aphelion and planetary nebulæ, the spectra are identical, consisting simply of magnesium radiation (δ 500). With the first increase of temperature continuous spectrum is added in both cases. As the nebulous swarm condenses an apparent star with a spectrum consisting of bright flutings and lines is the result, and this is also the case in cometary swarms. Still further condensation of the nebulous swarm results in a body of Group II., giving mixed carbon radiation and metallic fluting absorption, and this also is a well marked stage in the development of cometary spectra. Further condensation in both cases results in line absorption. Schiaparelli's view, therefore, that comets consist of nebulous materials drawn into the solar system by solar attraction, is now abundantly demonstrated by the spectroscopic study of nebulæ and comets. The discussion of cometary spectra therefore strengthens the general hypothesis, which would have been worthless had the cometary spectra been otherwise.

In the second part of the paper Mr. Lockyer proceeds to test his hypothesis by a discussion of the spectrum of the aurora. He points out that if in the aurora the solid particles of the meteorites which are constantly entering our atmosphere are acted upon by the electric current, the spectroscopic phenomena observed ought to be similar to those observed in our laboratories when meteoric dust is subjected to electric discharges in vacuum tubes. It has never been possible to reconcile the aurora spectrum with any known spectrum of air, and some investigators have attempted to get over this difficulty by assuming that the aurora is produced under conditions of temperature and pressure which we are unable to imitate in our laboratories. A comparison of the aurora spectrum with the spectra of meteorites and uncondensed meteor-swarms (γ Cassiopeiæ, &c.), however, indicates a very intimate relation between the two apparently different classes of phenomena. The meteoric dust theory of the aurora as first enunciated by Olinsted during the display of 1833 has practically been rejected because the lines of iron were not to be seen except in auroræ of exceptionally high temperature.

The principal line in the auroræ spectrum is shown to be in all probability the remnant of the manganese fluting at λ 558. This fluting is found in every meteorite which has been spectroscopically examined at a low temperature, and, moreover, it is seen long before the iron with which it is associated in meteorites. Even the small trace of manganese is suffi-

cient to render this fluting visible before the iron lines. The secondary lines seen in the aurora spectrum also appear to be due to constituents of meteorites, which are most volatile at the lowest temperatures. The reason why the lowest temperature spectrum in nebulæ should be that of magnesium, while in the aurora it is manganese, Mr. Lockyer explains is that in nebulæ heat due to collisions is in question, while in the aurora electrical conductivity as well as heat is in question. Magnesium, being mainly in combination with silica in meteorites, would not be so likely to appear in electrical excitations as would the volatile metallic constituents. There is therefore apparently strong evidence that the spectrum of the aurora is due to the presence of meteoric dust in the upper parts of the air, and the investigations strengthen the general meteoric hypothesis.

In the third part of the paper the hypothesis is further tested by a discussion of binary stars. If the apparently single variables of the Nova type are really double nebulæ, as the hypothesis supposes, visible physical doubles are probably only further advanced stages, and by an investigation of the spectra of the components, or of their colours where spectra are not available, it ought to be possible to determine the stage of condensation of such double nebulæ. The main idea that the component with the smallest *mass* will run through its changes at a greater rate than the other component.

According to the relative stages of development of the two components (or indirectly to their relative masses) Mr. Lockyer divides the known physical doubles into five classes. There are really only three cases in which the components do not appear to have condensed from double nebulæ and here the companions are probably additions of a cometary nature. The general view that the regular variables of Group II. are really double nebulæ is therefore strengthened by this investigation. The irregular variables of the group are regarded by Mr. Lockyer as multiple nebulæ, which will ultimately form multiple stars.

In a separate paper communicated to the Royal Society by Professor G. H. Darwin it is shown that there is no real antagonism between Mr. Lockyer's meteoric hypothesis and the nebular hypothesis of Kant and Laplace.

(6.) *The Bearing of the Meteoric Hypothesis on Solar Physics.*

The working out of the general meteoric hypothesis enables us to define the sun's exact place amongst the other

bodies of the universe. As far as can at present be stated, the sun belongs to one of the later stages of Group V., that is to say, it has already passed through the nebulous stage, and the stages represented by stars like α Orionis, α Tauri, and α Lyræ, and has still to pass through the stage represented by stars like 152 Selij. before it finally becomes a dark planetary body. There is evidence that the time taken for a nebulous swarm to reach the hottest stage is less than that taken for the subsequent cooling to the planetary stage, so that although the sun has already cooled very considerably, it is probable that it is still only about half way in point of time on its journey from the nebulous to the planetary stage.

The experiments on the spectra of meteorites are especially interesting in connexion with the probable meteoritic nature of the sun's atmosphere, and the theory which ascribes sunspots to falls of this meteoric matter into the photosphere.

The solar spectrum can be very nearly reproduced by taking the spectrum of a mixture of stony meteorites between the iron meteoric poles of an electric arc. Photographic comparisons of this kind, on a large scale, have been taken for the region of the spectrum lying between K. and D.

The absence of carbon and oxygen from the sun (or their presence in very small quantities) and the presence of hydrogen also receive explanation by the meteoric hypothesis. It is known that the vapours in the heads of comets are driven outwards from the sun by some repulsive force. If this force is so intense at cometary distances, it may fairly be expected that it will also exist at the sun's surface, and consequently the permanent gases will be repelled. In this way the absence of oxygen and compounds of carbon is accounted for. Hydrogen is also repelled in a similar manner, but as quickly as it is driven away more is formed by local dissociation.

Another reason for the absence of carbon is, that if it by any means could descend as low as the photosphere, it would be immediately dissociated.

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